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THE COMPARATIVE OSTEOLOGY OF THE SCOMBROID FISHES OF THE GENUS *SCOMBEROMORUS* FROM FLORIDA^{1,2}

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ABSTRACT

Three species of *Scomberomorus* found in Florida, the Spanish mackerel (*S. maculatus*), the cero or painted mackerel (*S. regalis*) and the king mackerel or kingfish (*S. cavalla*) are the subject of a comparative osteological study. A brief discussion of the possible relationships within the genus and possible relations of *Scomberomorus* to other genera is presented.

In comparing the osteology of the three Florida species it was noted that both *S. maculatus* and *S. regalis* showed many characters in which *S. cavalla* stood apart. It was therefore concluded that *S. cavalla* was a divergent member of the genus.

It is suggested that the two Atlantic groups (*cavalla* and *regalis-maculatus*) exist on a world-wide basis, western Pacific forms (*Cybium*) being assignable to one or the other group.

INTRODUCTION

The three species of *Scomberomorus* found in Florida, the Spanish mackerel (*S. maculatus*), the cero or painted mackerel (*S. regalis*) and the king mackerel or kingfish (*S. cavalla*), are the subject of one of the most important commercial fisheries in the State. All are desired game species, especially *cavalla* which attains a large size. They are apparently the only representatives of *Scomberomorus* in the western North Atlantic.

The genus *Scomberomorus*, along with *Cybium*, *Acanthocybium* and several other genera, has often been placed in a distinct family, the Cybiidae, by authors, notably Kishinouye (1923). The cybiids are here included in the family Scombridae.

Little has been published on the osteology of the group, the notable exceptions being Kishinouye's (1923) treatment of western Pacific scombroids, and that of Conrad (1938) on *Acanthocybium*. Few

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other authors have treated any species of *Scomberomorus* in any detail. Starks (1910) dealt with *S. sierra* from Mazatlan, Mexico, and *S. maculatus* from Chesapeake Bay. Regan (1909) presented only a generalized account on scombroids.

Several other works, although dealing with other genera, have been valuable references in this study and should properly be mentioned here. Godsil and Byers (1944) and Godsil (1954) published comprehensive studies on tunas and tuna-like fishes. Allis (1903) monographed the anatomy of *Scomber*. The work by DeSylva (1955) on *Thunnus atlanticus* has been especially useful in outlining this study.

The present work offers a comparative description of the osteology of the three species of western Atlantic *Scomberomorus* based on Florida and Bahaman material. A brief discussion of the relations of these species to other extralimital forms is given and possible relations of *Scomberomorus* to other genera are treated.

In comparing the osteology of the three Florida species it was noted that *maculatus* and *regalis* share many characters in which *cavalla* stands apart. In general the description given below is first that of *cavalla* and then those features in which *maculatus* and *regalis* differ are mentioned.

In the course of this study I have necessarily called upon numerous persons at The Marine Laboratory, University of Miami, for help and material, and it is a pleasure to acknowledge my indebtedness and extend my sincere thanks to all.

I am grateful to Dr. C. Richard Robins for direction and advice. Drs. Gilbert L. Voss, C. P. Idyll and Hilary B. Moore have given much valuable advice and have aided in numerous other ways. Dr. Charles E. Lane provided X-rays, pictures and photographs on which some of the plates are based.

Numerous persons obtained the specimens which made this study possible. In this regard I am grateful to many boat captains at Pier 5 in Miami, to Edward Klima and to Dr. C. Richard Robins.

Finally, I wish to express my gratitude to my wife for her assistance in the preparation of the material.

MATERIALS AND METHODS

The majority of the fishes examined were obtained from local anglers and charter and party boat captains. The specimens of cero mackerel (*S. regalis*) were secured from Cat Cay in the western Bahamas.

A total of 32 specimens were examined, including 15 Spanish mackerel (*S. maculatus*), 12 king mackerel (*S. cavalla*) and 5 cero mackerel (*S. regalis*). Their range in fork length was as follows: *S. cavalla*, 22.3 to 160 cm, *S. maculatus*, 25.4 to 53.3 cm and *S. regalis*, 27.2 to 57.5 cm.

Skeletons were prepared for study by cooking the fresh fish in water just long enough to loosen the tissues from the bones. The bones of *Scomberomorus* are very oily and therefore it was necessary to bleach them in a dilute solution of commercial "Clorox" (sodium hypochlorite).

In naming the various parts of the skeleton Starks (1901), Kishinouye (1923), Gregory (1933), Ford (1937), Whitehouse (1910), and Conrad (1938) are followed. No new terms are employed.

In the vertebral counts, the first haemal arch is the one where the haemapophyses are fused but do not bear a spine. The first appreciable haemal spine is defined as forming the boundary between the pre-caudal and caudal vertebrae.

All material used here is catalogued and deposited in the fish collection of the University of Miami Marine Laboratory. All illustrations were prepared by the author.

The following numbers designate the bones of the neurocranium and tail segment in the plates:

- | | |
|--------------------|--------------------------------|
| 1. dermethmoid | 13. prootic |
| 2. parethmoid | 14. exoccipital |
| 3. nasal | 15. parasphenoid |
| 4. vomer | 16. basioccipital |
| 5. alisphenoid | 17. basisphenoid |
| 6. frontal | 18. epural |
| 7. parietal | 19. dorsal caudal radials |
| 8. epiotic | 20. hypural plate |
| 9. sphenotic | 21. hypural |
| 10. pterotic | 22. specialized neural process |
| 11. opisthotic | 23. centrum |
| 12. supraoccipital | |

OSTEOLOGY

The external body form of *Scomberomorus* reflects in its modifications the fast swimming habits of these fishes. The bones are generally weak and brittle and highly impregnated with oil. The surface bones are very thin and smooth.

According to Kishinouye (1923: 309), the Cybiidae, considered here as a group within the Scombridae, present a gradual transformation to the higher group of the Plecostei (Thunnidae). Starks (1910: 83), in a phylogenetic tree illustrating relationships, based on cranial characters of various genera of the Scombridae and Thunnidae, puts *Scomber* in the trunk of the tree, *Scomberomorus* and the tunnies (*Thunnus*, *Auxis* and *Gymnosarda*) on opposite branches, while *Sarda*, which combines the cranial characters of the two branches, stands between them.

The main features of the skeleton may be summarized as follows:

Bones all light, fibrous and oily.

Neurocranium elongated, trapezoidal, and with its dorsal surface somewhat flattened.

Supraoccipital crest low and carried forward by the frontals to the dermethmoid.

Temporal ridges directed straight forward and not interrupted above the eyes by a transverse ridge.

An accessory ridge developed between the temporal and pterotic ridges.

Pterotic ridge extended forward to about the middle of the orbit.

Dermethmoid forked and concave in front to receive the pre-maxillary processes.

Vomer oval in shape, projecting forward from the floor of the skull and bearing a patch of small villiform teeth.

Nasals wide, attached for their full length to the side of the frontal and dermethmoid and not projecting beyond the latter.

Maxillaries with an auxiliary element on their upper edges.

Posterior end of the upper jaw rounded and its lower margin nearly straight, formed by the premaxillaries only.

Teeth large and laterally compressed, the number highly variable with age and species.

Eyes seated in heavy sclerotic capsules.

Infraorbital ring reduced and incomplete, the bones mingled with the surrounding scales of the orbit.

Head of the hyomandibular where it articulates with the neurocranium divided into two branches.

Preopercle unarmed and serrated on both the superior and posterior margins.

Posttemporal attached directly to the superior surface of the opisthotic.

Pterorics not produced backward in elongated spines.

Alisphenoids not fused in the median line.

Two rows of dentigerous ossicles encountered on the branchial arch.

First vertebra (atlas) considerably reduced.

Neural and haemal spines slender, and fragile. Neural spines of first six vertebrae broad.

Hypural plate entirely hidden by the bases of the caudal rays.

No lateral bony caudal keel.

NEUROCRANIUM

The neurocranium (Plates I-III) of *Scomberomorus* is more or less trapezoidal in shape when viewed dorsally. It is elongate and flat, particularly at the anterior region and is deepest at the hind end of the orbit.

The dorsal surface is marked by a median ridge and three grooves on each side: dilator, temporal and supratemporal (Allis, 1903: 49). These grooves are separated from each other by two ridges of bone. Thus, there are six grooves and five ridges in all.

The median ridge is carried forward by the frontals to the dermethmoid and is prolonged posteriorly in a large supraoccipital crest. This crest extends down over the exoccipital suture more broadly than in any other genus of the Scombridae, except *Acanthocybium*, though it is not at all interposed between them (Starks, 1910: 89).

The internal ridge or temporal ridge of Starks is almost straight in *cavalla* but curved inward in both *maculatus* and *regalis*. Anteriorly, the ridge almost reaches to the posterior portion of the nasal and it is not interrupted above the eyes by any transverse ridge. Posteriorly, the ridge is prolonged in a flap-like projection in both *maculatus* and *regalis*, but *cavalla* lacks this projection.

The external or pterotic ridge extends forward to the mid-level of the orbit and develops anteriorly a small auxiliary ridge which is somewhat lower in *cavalla* than in the other two species.

The dilator groove is shorter than the other two and can be easily detected in lateral view (Plate III). The temporal groove is the middle one and is deeper than either of the two. The remaining groove, the supratemporal, is the largest of the three and opens posteriorly between the supraoccipital crest and the middle portion of the epiotic.

There are two conspicuous triangular depressions located symmetrically on either side of the supraoccipital and at the posterior opening of the temporal groove.

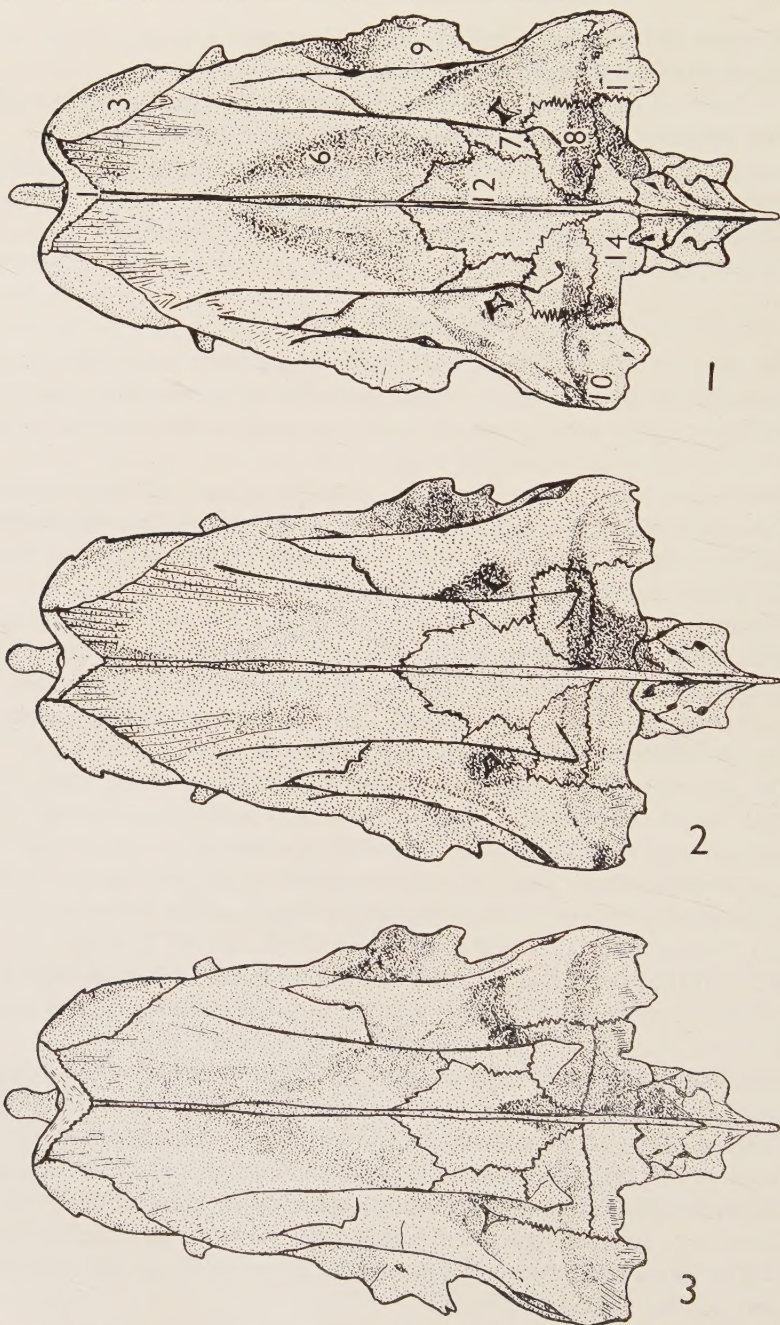


PLATE I. Neurocranium, dorsal view. 1. *S. cavalla*. 2. *S. maculatus*. 3. *S. regalis*.

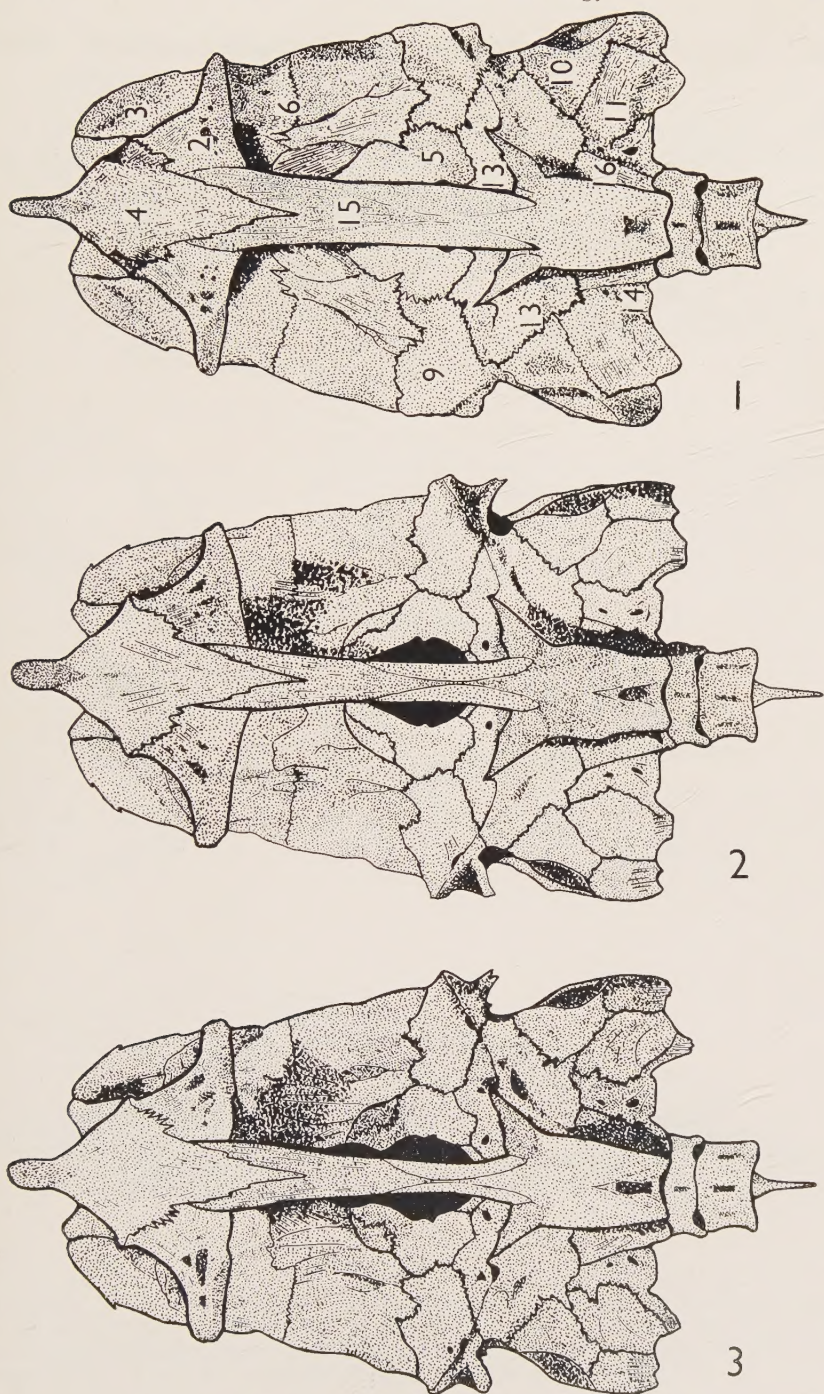


PLATE II. Neurocranium, ventral view. 1. *S. cavalla*.
2. *S. maculatus*. 3. *S. regalis*.

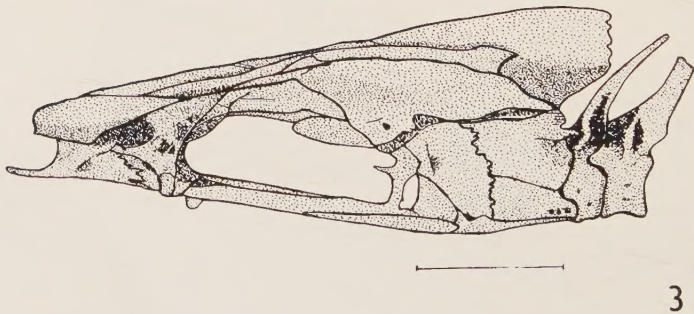
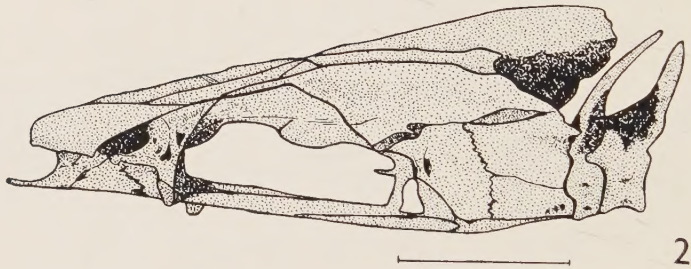
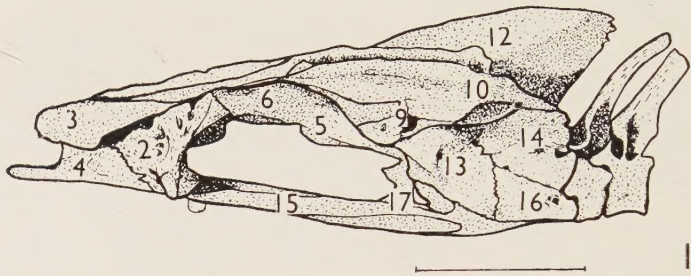
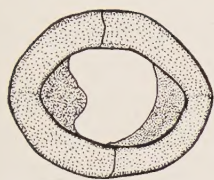
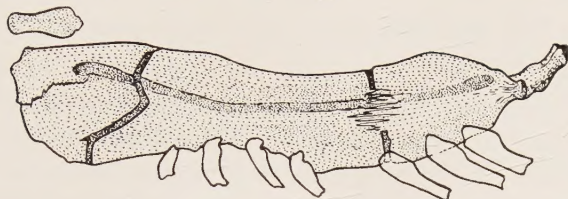


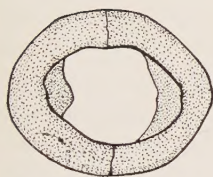
PLATE III. Neurocranium, lateral view. 1. *S. cavalla*.
2. *S. maculatus*. 3. *S. regalis*.



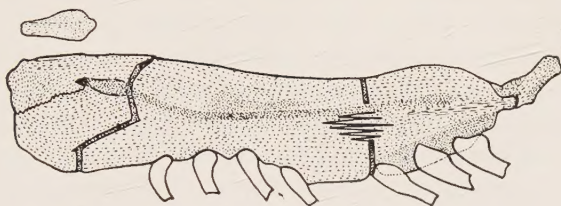
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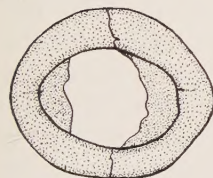
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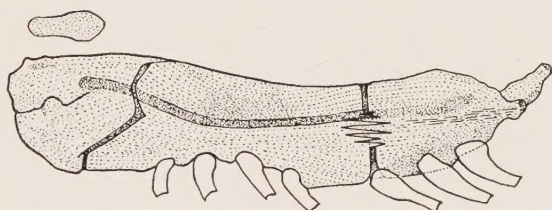
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PLATE IV. Sclerotic capsule (1-3); external view of part of left hyoid arch (4-6), from left to right: glossohyal, basihyal, ceratohyal, epihyal and interhyal, branchiostegals represented by basal portions only; external view of left lacrimal (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

The orbits are large and occupy almost one-half the length of the neurocranium.

Olfactory region.—The dermethmoid is a forked median bone overlapped above by the frontals. The dermethmoid is concave in front to articulate the premaxillary processes and it is bounded ventrally by the vomer and the parethmoid. At the anterolateral portion the dermethmoid supports the nasals. There are no differences among the compared species.

The parethmoids (=prefrontals) are paired bones forming the anterior wall of the orbit and the posterior and mesial walls of the nasal cavity. The bones are loosely attached one to the other as well as with the boundary bones, except the vomer. They are massive, bear well-developed cellular-oil reservoirs, and their external surfaces which line the nasal cavity are cellular and irregular. On the dorsal surface the parethmoids abut against the nasal anteriorly, the frontals posteriorly, and medially both are connected to the dermethmoid. The parethmoids are longer than broad and have only one articulating surface for the palatine (Kishinouye, 1923: 313). No differences were found in any of the compared species.

The nasals are triangular-shaped, flat bones, united for their full length to the external edge of the frontals and the extremities of the branches of the forked dermethmoid. The external edges of the nasals are thickened and form an irregular contour when viewed dorsally. The bones do not project beyond the dermethmoid. With respect to the nasals, *Scomberomorus* closely resembles *Acanthocybium*, which has similar triangular, non-projecting nasals (Conrad, 1938: 2). No differences among the three species of *Scomberomorus* were detected.

Ventrally, both dermethmoid and parethmoid connect with the vomer, which is an elongated, anterior median bone, thickened anteriorly and bearing a large patch of fine villiform teeth on its ventral surface. The vomer lies below the parasphenoid, with which it firmly connects. The head of the vomer is more or less spatulated and is noticeably thicker in *cavalla* than in both *maculatus* and *regalis*. The bone articulates indirectly, on each side, with the corresponding maxillary.

Orbital region.—The paired frontals form the largest portion of the dorsal surface of the skull. The bones are pointed anteriorly, diverging to expose the dermethmoid, while posteriorly they are broad.

The frontals fail to close over the entire length of their contact, and

this seems to be a typical scombroid aberration (Conrad, 1938: 6). A large slit is found between the frontals at the level of the alisphenoids. This slit is larger and conspicuous in *cavalla* while it is carried a little forward and is almost inconspicuous in both *maculatus* and *regalis*. Rivas (1953: 170) in his study of the bluefin tuna, *Thunnus thynnus*, termed this slit the pineal window.

The centers of the frontals are hollow and present a series of radiating growth lines which are very clear at the anterior end. The lateral internal sides are raised to form the median ridge, which carries the supraoccipital crest to the dermethmoid.

Anteriorly, the frontals lie on the dorsal surface of the parethmoids and the posterior end of the dermethmoid. Laterally, the frontals are thickened to form the roof of the orbit. Posteriorly, they connect with the supraoccipital, parietals, pterotics, sphenotics, and alisphenoids.

The alisphenoids are paired bones, roughly rectangular in shape, which form the main portion of the hind end of the orbit's roof. As in all scombroids, they do not contact the parethmoids.

The brain chamber opens between the alisphenoids; its aperture is wider in both *maculatus* and *regalis* than in *cavalla*.

Because the parasphenoid of *cavalla* is broader than in the other two species, the brain chamber is almost unnoticeable when the neurocranium is viewed ventrally, (Plate II, Fig. 1) and so is the separation between the alisphenoids. The reverse holds true with both *maculatus* and *regalis*, particularly in the latter where the opening of the brain chamber is considerably exposed, (Plate II, Figs. 2 and 3).

The anterior end of the alisphenoids is more or less turned downward. Posteriorly, the bones connect the basisphenoid and prootics, and laterally contact the frontals and sphenotics.

In common with most scombrids, *Scomberomorus* has heavy sclerotic capsules (Plate IV, Figs. 1-3) divided into two pieces: anterior and posterior. The capsules are ovate rather than rounded.

The lacrymal (Plate IV, Figs. 7-9) is the first bone of the circum-orbital series, and is characterized by the sculpture which decorates it. The bone is directed upward and forward hiding the major portion of the maxillary. The posterior end is considerably elongated. The dorsal surface bears an articular cup-like surface to the palatal process of the parethmoid. The anterior end is rounded in *cavalla* while it is rather forked in the other two species.

The lacrymal is traversed by the sub- and antorbital parts of the

main infraorbital lateral canal of the lateral-line system, the canal ending near the anterior end of the bone (Allis, 1903: 113).

The circumorbital bones posterior to the lachrymal are indistinguishable from the thick scales surrounding the orbit. However, one of them has a flag-like appearance which permits its identification without any doubt.

The orbitosphenoid is lacking in *Scomberomorus* as in *Acanthocybium* and *Scomber*.

Otic region.—In *Scomberomorus*, the parietals are paired irregular bones located on both sides of the supraoccipital, and bear dorsally an elevated longitudinal ridge, which constitutes a segment of the temporal ridge mentioned above. Their anterior margins firmly connect the frontals, while their posterior ones unite with the epiotics. The parietals are separated from the pterotics and take almost no part in the formation of the roof of the brain cavity (Kishinouye, 1923: 316).

The supraoccipital forms dorsally the median portion of the posterior end of the neurocranium and bears a well-developed ridge which is continued anteriorly by the frontals to the dermethmoid and produced posteriorly into the strong supraoccipital crest. The ridge extends down over the exoccipitals suture, but it is not at all interposed between them. The supraoccipital is bounded anteriorly by the frontals and laterally by the parietals and epiotics. Parietals and supraoccipitals are very similar in all the species studied.

The pterotics form the lateral posterior corners of the skull and are slightly produced backward into a more or less truncate process. This condition is strikingly different than in *Acanthocybium* and other scombrids, where the pterotic processes form sharp spines. The pterotics constitute a part of the temporal and dilator grooves and also the main portion of the pterotic ridge. Ventrally there is an oval depression to articulate the hyomandibular. No differences can be pointed in the three species.

The prootics are irregularly shaped bones which can be easily located on the ventral side of the neurocranium. They connect with all the cranial bones, except the parietals and supraoccipital, and lodge the major portion of the auditory organ. The ventral edges are cut out by a semicircular opening through which the internal carotid artery enters the eye-muscle canal (Allis, 1903: 90).

The prootics internally bound the epiotics, massive, folded bones which form the dorso-posterior part of the otic capsule. The epiotics

have two well-marked surfaces: dorsal and posterior, separated by a strong rounded edge. Dorsally there is a rough process that receives the dorsal branch of the posttemporal, thus forming a connection between the pectoral girdle and the neurocranium. This process forms the terminal posterior end of the temporal ridge and is rather short in *cavalla*, while it is expanded posteriorly in both *maculatus* and *regalis* (Plate I, Figs. 1-3). Internally, the epiotics bear a deep sulcus to receive the anterior semicircular canal of the auditory organ, (Kishinouye, 1923: 317).

The epiotics connect posteriorly with the exoccipitals in an almost straight suture, anteriorly with the parietals, and laterally with the supraoccipital and pterotics.

The sphenotics form ventrally the posterior part of the orbital roof and laterally a segment of the articular fossa for the head of the hyomandibular. The shallow dilator grooves are on the surface of the sphenotics.

The sphenotics are flattened and bear a mid-lateral projection which is larger in both *maculatus* and *regalis* (particularly in the latter) than in *cavalla*.

The opisthotics are as much on the dorsal as on the ventral surface of the neurocranium, and are interposed between the pterotics and exoccipitals. The opisthotics are irregular, scale-like, and bear a protuberance to receive the ventral branch of the posttemporal. The hind margins are the thickest portions and present two backward projections, which are more conspicuous in *regalis* than in the other two species.

The exoccipitals enclose the foramen magnum and widely connect with the basioccipital. Their vertebral or paraoccipital condyles to the atlas are large, concave, and project a little over the basioccipital. The ventral surface is slightly concave and bears two noticeable pits, the foramina of the vagus and glossopharyngeal nerves; the latter is the smaller of the two.

The supraoccipital crest extends broadly over the suture between the two exoccipitals, although it is not interposed between them.

Basicranial region.—The parasphenoid (Plate II, Figs. 1-3) is a long blade-shaped bone that forms the greater portion of the basicranial region of the neurocranium. It runs almost the entire length of the ventral median line and relates the posterior otic region with the parethmoids, dermethmoid, and vomer on the anterior olfactory region.

The parasphenoid has a long body and bears posteriorly two lateral ascending wings, one on either side, to connect the prootics. Behind these wings the parasphenoid is wider and smoothly curved upward. At the posterior end the parasphenoid is embraced by the ventral sides of the basioccipital and bears a deep rectangular channel, which forms the bottom of the eye-muscle canal (Allis, 1903: 90). The anterior end is bifurcate and is overlapped ventrally by the posterior portion of the vomer. On the ventral surface and at the point of origin of the lateral wings, there is a noticeable median keel which separates the surfaces of insertion of the palatine's adductor muscles of both sides of the head (Allis, 1903: 91).

The parasphenoid of *cavalla* is broader than in the other two species. At the same time, the median keel is somewhat different because it forms a cutting-edge in both *maculatus* and *regalis*, while in *cavalla* the edge of the keel is flat.

The basisphenoid is a small, median, Y-shaped bone, which unites the parasphenoid to the prootics and alisphenoids. The median vertical process is laterally compressed and divides the mouth of the myodome into two (Kishinouye, 1923: 317). This median process bears an anterior projection, which is broad in *cavalla*, but almost needle-shaped in both *maculatus* and *regalis*.

The remaining bone of the basicranial region, the basioccipital, is relatively narrow and bears the concave, rounded occipital condyle that articulates the atlas. The posterior portion of the basioccipital is vertebra-like in shape and is completely occupied by a deep conical concavity, which leaves just a narrow external lamina at the posterior end of the bone. The anterior portion is a little expanded and is broader than the solid hind end. The ventral portion is slightly curved upward.

The basioccipital supports dorsally the exoccipitals of the corresponding side of the neurocranium, and is bounded ventrally by the parasphenoid, and in front by the prootics.

Other than the differences mentioned in the para- and basisphenoid, the bones are similar in the three species.

BRANCHIOCRANIUM

Oromandibular region.—The premaxillary (Plate VI, Figs. 1-3) of *Scomberomorus* is a long, curved bone pointed anteriorly. The ascending and descending processes are thickened. These processes exhibit differences among the species in question: they are more pointed

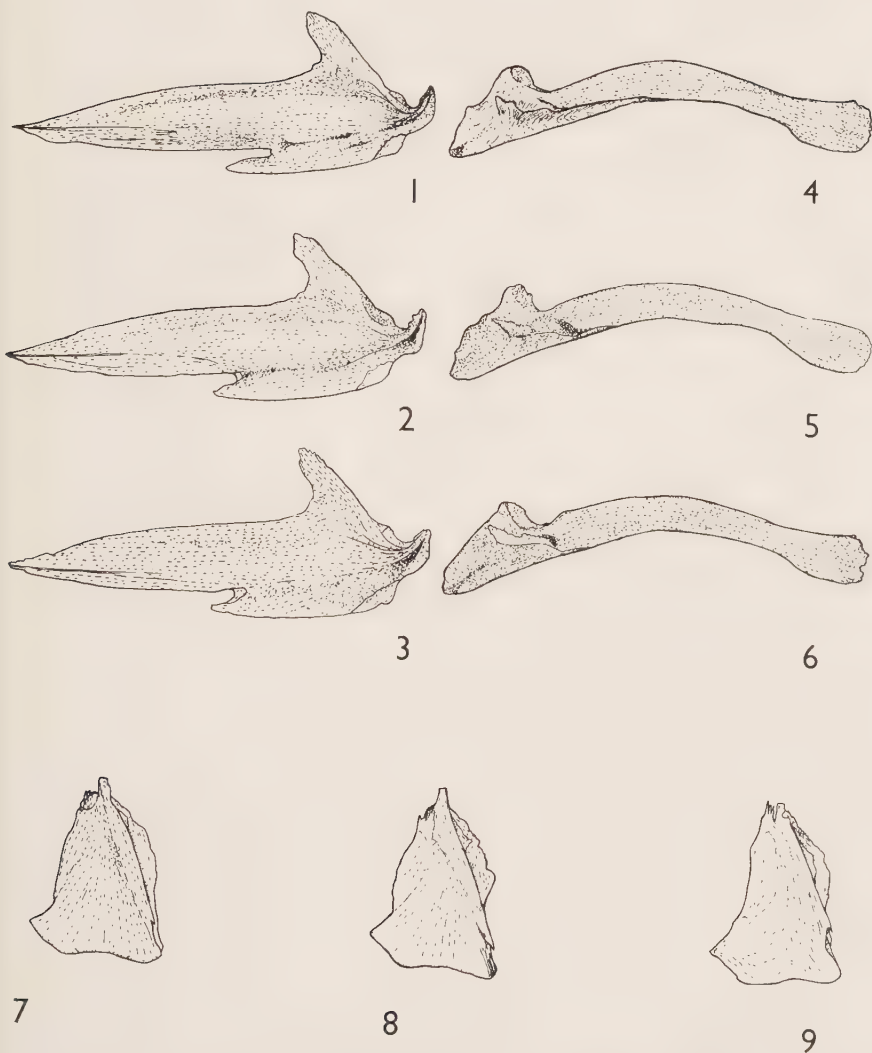


PLATE V. External view of left articular, with angular attached (1-3), left maxillary (4-6), and left metapterygoid (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

in *regalis* than in both *cavalla* and *maculatus*. The nasal process of the premaxillary projects into the concavity in front of and over the dermethmoid.

The number of premaxillary teeth varies with the size of the fish. The

larger king mackerel (*cavalla*) possess the larger number of teeth. The number of teeth has been used by Jordan and Evermann (1896: 873), and Meek and Hildebrand (1923: 322) as a specific character, but this is not justified.

In the angle between the posterior margin of the ascending nasal

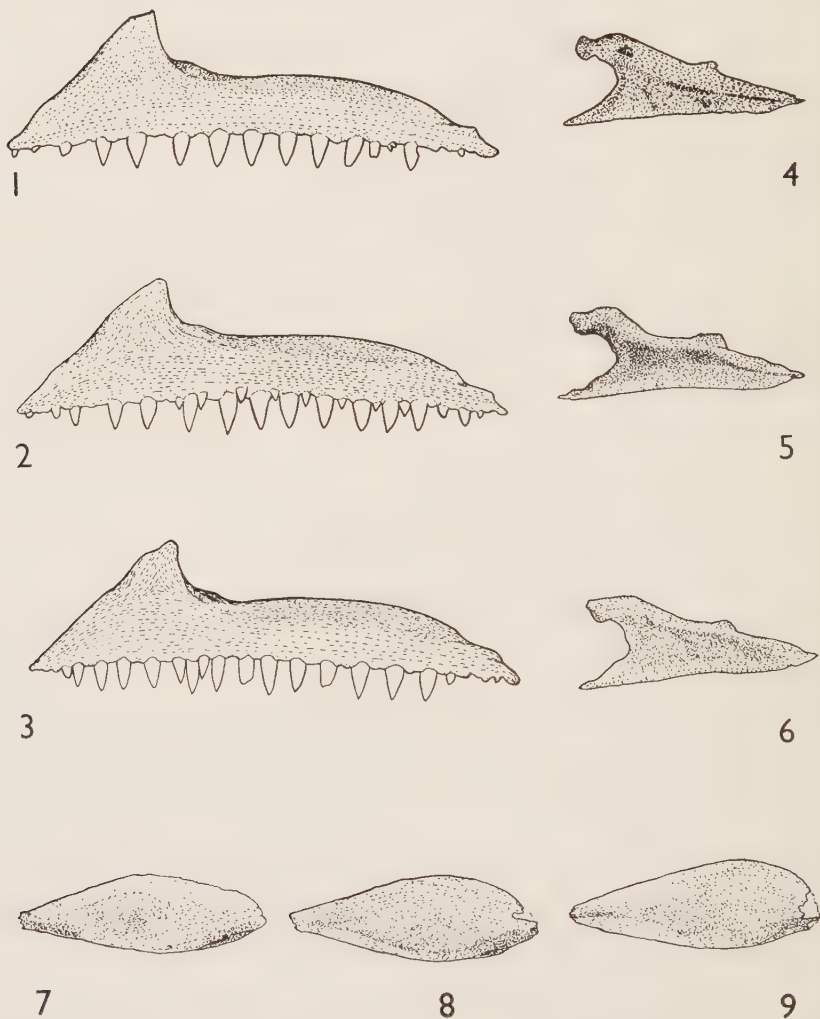


PLATE VI. External view of left premaxillary (1-3) and left palatine (4-6), and dorsal view of left entopterygoid (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

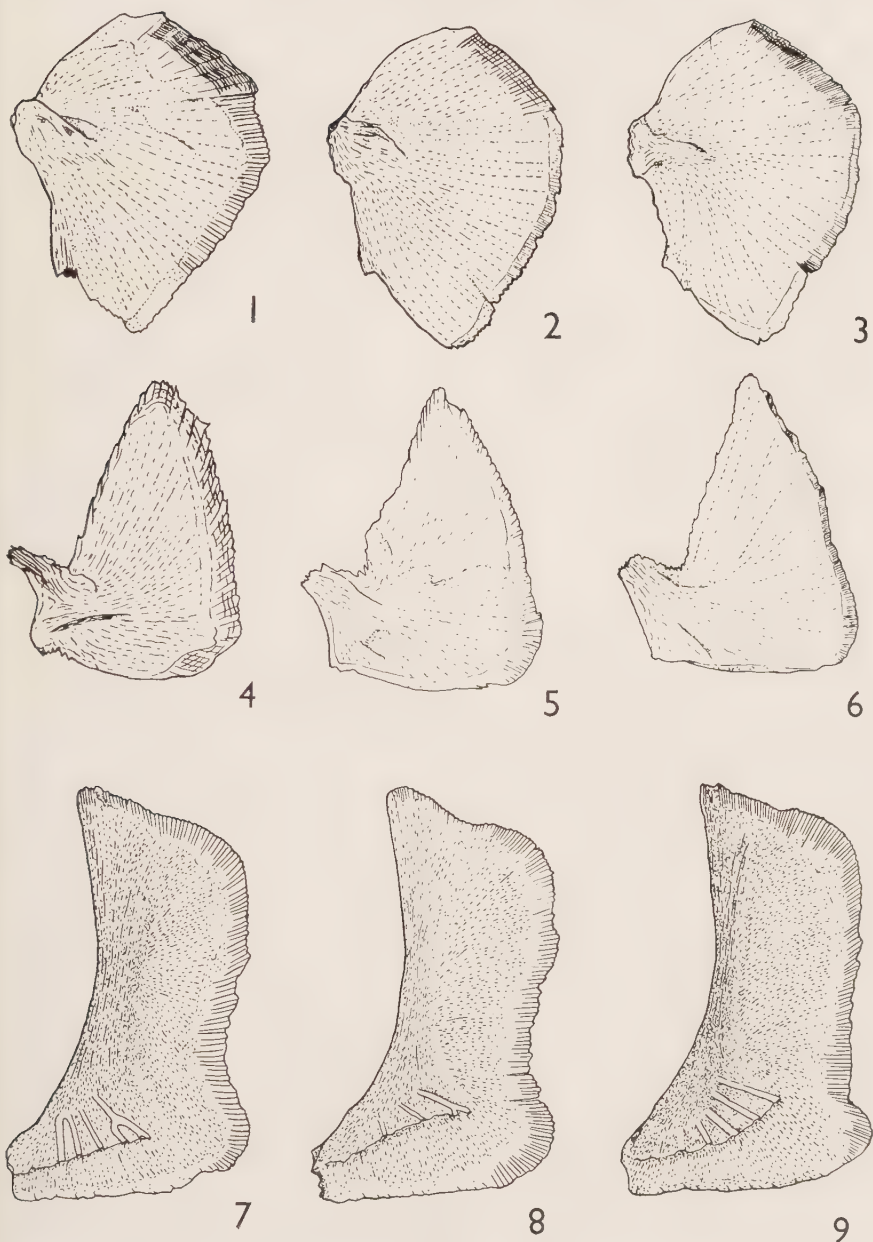


PLATE VII. External view of left opercle (1-3), subopercle (4-6) and preopercle (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

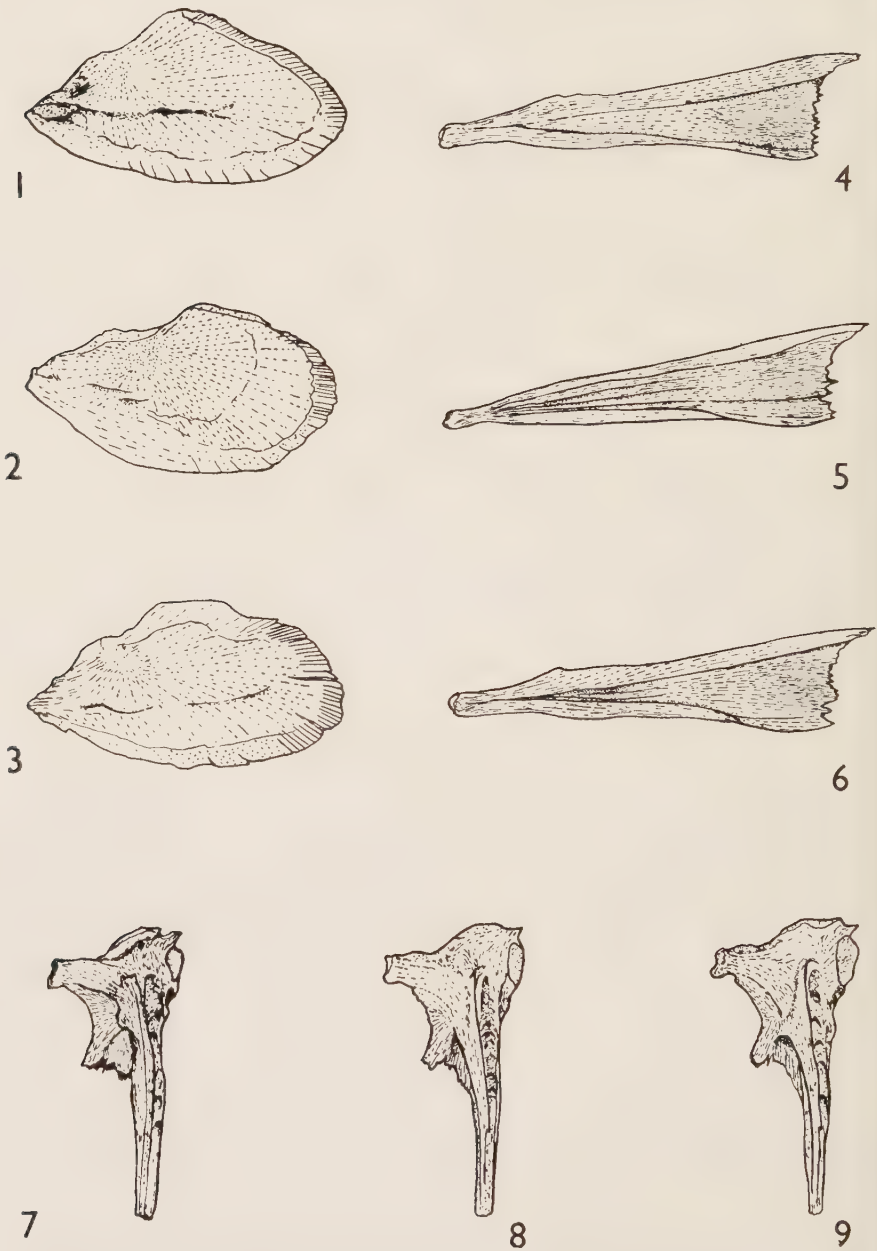


PLATE VIII. External view of left interopercle (1-3), urohyal (4-6) and hyomandibular (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

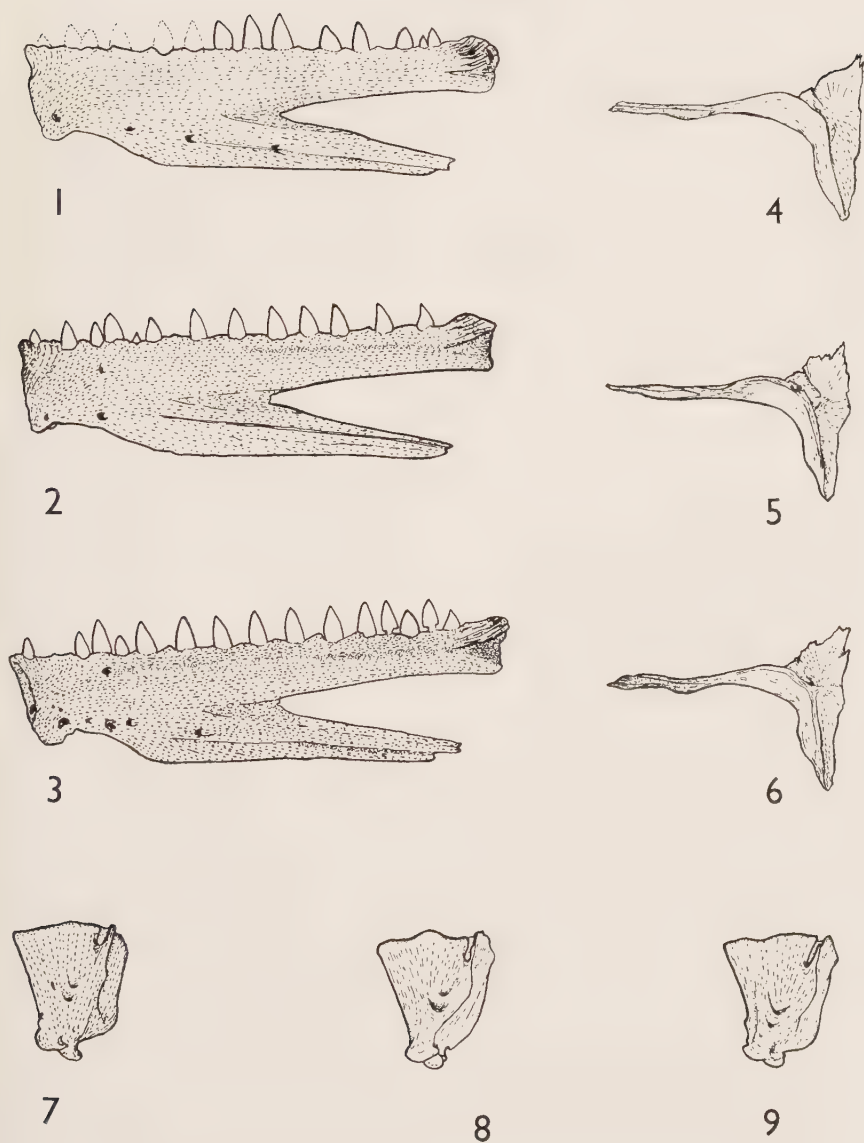


PLATE IX. External view of left dentary (1-3), ectopterygoid (4-6), and quadrate (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

process of the premaxillary and the dorsal edge of the shank of the bone there is a small projecting edge which has two articular facets. These facets are more noticeable in *cavalla* than in the other two species.

The maxillary (Plate V, Figs. 4-6) is also a long, curved bone that joins the premaxillary on its postero-dorsal surface. The anterior end is thickened and blunt. The head is low, grooved at the ventral side, and carries several articular surfaces to the vomer above and the premaxillary below. The posterior end is broad, thin, and flattened and is surmounted by a small scale-like auxiliary or supra-maxillary bone. There are only minor differences among the maxillaries of the compared species.

The dentary (Plate IX, Figs. 1-3) is a large forked bone which forms the basis of the lower jaw. It is laterally flattened and bears a single row of triangular, sharp teeth on the dorsal arm. The ventral arm is relatively narrower and shorter than the dorsal one and its inferior margin has a sulcus which lodges the articular and the anterior end of the Meckel's cartilage. The dentary is slightly curved when viewed dorsally and forms a solid unit with the articular and the Meckel's cartilage. The anterior end is joined with its fellow of the opposite side by means of a symphysis. The base of the ventral arm presents a series of orifices, the preoperculo-mandibular primary pores (Allis, 1903: 181), which represent the external apertures of a branch of the lateral-line system.

The dentary does not vary notably within the three compared species; however, the ventral arm is somewhat broader in *cavalla* than in both *maculatus* and *regalis*.

The articular (Plate V, Figs. 1-3) is a spear-shaped bone which is concave internally and convex externally. Its convexity is adjusted to the general curvature of the dentary which it joins. The posterior end of the articular bears three large processes: one dorsal which is directed forward and upward, one ventral which is directed forward and another which is directed backward and upward and is located at the posteriormost part of the bone. The latter process has a hook-like appearance and carries a transverse articular facet to the quadrate. Between the dorsal and ventral processes is the Meckel's cartilage which extends directly forward into the space between the two arms of the dentary. The articular is very similar in the three species, except in the ventral process which is larger and narrower in *cavalla* than in both *maculatus* and *regalis*.

On the postero-ventral surface of the articular is firmly joined the angular, a small irregular bone whose ventral edge projects downward beyond the ventral edge of the articular. The angular is alike in all the compared species.

The metapterygoid (Plate V, Figs. 7-9) is a flat bone somewhat triangular in shape. Its postero-dorsal margin is bifurcated to receive the stem of the hyomandibular and its anterior margin is more or less straight. The ventral margin is undulated and borders the quadrate and symplectic. The uppermost portion of the metapterygoid is strongly connected with the lamellar region of the hyomandibular. The posterior edge of the ventral margin abuts against the lowermost portion of the stem of the hyomandibular, but this edge does not touch the hyomandibular, a relatively long slit being left between the two bones, through which the arteria hyoidea passes (Allis, 1903: 152). The features of the metapterygoid are very similar among the three species, but in *regalis* the anterior margin is decidedly concave, while in *cavalla* and *maculatus* it is more or less straight or slightly convex, respectively.

The internal surface of the metapterygoid bears at the antero-ventral end an articular facet to the ectopterygoid (Plate IX, Figs. 4-6) which is a T-shaped bone, the top of the "T" forming its posterior end. The ectopterygoid is joined with the entopterygoid dorsally, the palatine laterally and anteriorly, and the quadrate and metapterygoid posteriorly. The shank of the "T" is slightly curved in the top view and is concave, dorsally, and convex, ventrally. The ventral convexity forms part of the buccal cavity. The ectopterygoid is alike in the three species.

The entopterygoid (Plate VI, Figs. 7-9) is long, thin and flat and connects with the palatine, metapterygoid and ectopterygoid and lies on the parasphenoid with its mesial and posterior edges free from contacts. The dorsal surface of the entopterygoid is concave when viewed dorsally and somewhat narrower at its posterior end in *cavalla* than in the other two species. The ventral surface is smooth without a denticulous area of any kind.

The palatine (Plate VI, Figs. 4-6) runs forward on the external side of the vomer and hooks over the anterior end of the maxillary, immediately ventral to the nasal. Along the ventral edge of the palatine there is a rather stout vertical lamina armed with very fine granular teeth on its ventral surface. When viewed laterally, the palatine is roughly triangular in shape and presents a strong hook-like process at its anterior end, which is more or less constricted in *cavalla* but not so

in the other two species. At the mid-dorsal edge of the palatine, there is a small projection which is more developed in *maculatus* than in both *cavalla* and *regalis*. Posteriorly, the palatine is pointed and connects with the ento- and ectopterygoid.

The quadrate (Plate IX, Figs. 7-9) has the form of a triangle with its shortest side directed upward and abutted against the ventral border of the metapterygoid. The inferior portion bears a deeply concave articular surface to the corresponding surface on the hook-like and posteriormost process of the articular. At the lower posterior side there is a thickened portion, grooved on its inner surface and presenting a strong process directed upward and more or less pointed at its extremity. This process receives the preopercle at its dorsal end. The quadrate is very similar in the three species, but in *cavalla* the triangular outline of the bone is less equilateral than in the other two species.

The groove on the inner surface of the quadrate lodges the symplectic, a small, narrow bone which does not entirely fill the groove. The symplectic is not noticeably produced from the quadrate and is only clearly visible when the latter is viewed internally. The symplectic is connected with the lower end of the hyomandibular by a cartilage.

Hyoid-opercular region.—The opercle (Plate VII, Figs. 1-3) is a thin bone more or less broad and pentagonal in shape. It is divided into two portions by a horizontal smooth ridge which extends from the posterior margin to the uppermost part of the articular cup. The superior portion is thinner than the inferior portion. The posterior margin is more or less serrated. The articular cup for the opercular process of the hyomandibular is narrow and elongated. The anteroventral margin of the opercle bears a small projection which is well-developed in *cavalla*. The general shape of the opercle is somewhat different in *cavalla*, being broader from the anterior to the posterior margin than in *maculatus* and *regalis*. The anteroventral margin of the opercle is overlapped externally by the hind edge of the preopercle.

The subopercle (Plate VII, Figs. 4-6) is triangular in shape. The bone has a process directed forward and upward and connected with the preopercle. The dorsal portion of the subopercle is more acute in *regalis* than in both *cavalla* and *maculatus*.

The interopercle (Plate VIII, Figs. 1-3) is somewhat oval in shape. The bone forms the ventral free edge of the gill cover and is serrated at the posterior and ventral margins. The longest axis of the bone lies

in a horizontal position. The inner surface bears a small cup for articulating the ceratohyal. There are no appreciable differences among the three species.

The preopercle (Plate VII, Figs. 7-9) is a large crescent-shape bone with its anterior edge thickened and bearing a groove for articulating the hyomandibular, symplectic, and quadrate. The preopercle is broader at the ventro-posterior angle than at the dorso-posterior one. The horizontal limb is less developed than the vertical one. There are no differences among the three species.

The hyomandibular (Plate VIII, Figs. 7-9) is rod-shaped with a broad upper portion. The broader portion bears two condyles for articulating the neurocranium by means of two facets: one in the postero-inferior face of the sphenotic and the other on the ventral surface of the pterotic. A third condyle articulates the opercle posteriorly. A small pointed process is found behind the middle condyle. This is in contradiction to the findings of Kishinouye (1923: 322), who states such a process is absent in mackerels although present in other scombroids.

Anteriorly, the ventral surface of the hyomandibular connects the metapterygoid, the symplectic, which is directed antero-ventrally, and the interhyal, which is oriented along the axis of the stem. The posterior portion of the stem presents a deep groove which articulates the anterior surface of the vertical limb of the preopercle.

The stem of the hyomandibular is separated into anterior and posterior portions by a strong ridge which extends from the ventral end upward and forward in a slightly curved line almost to the dorsal margin. This ridge approaches the dorsal margin more in *cavalla* than in the other two species.

Between the ventral margin of the anteriormost condyle and the anterior margin of the stem of the hyomandibular below it, there is a wide lamella. This lamella is somewhat wider in *cavalla* than in both *maculatus* and *regalis*.

Aside from the differences mentioned above, the hyomandibular is alike in the compared species.

The hyoid complex (Plate IV, Figs. 4-6) of *Scomberomorus* contains, in addition to the glossohyal, which is embedded in the tissues of the tongue, four separate bones: the basihyal, ceratohyal, epihyal, and interhyal. These pieces are connected together by means of a hard cartilage which maintains the bones solidly attached. The interhyal articulates posteriorly the complex to the hyomandibular and symplec-

tic through an intervening cartilage, while the basihyal connects the anterior end to its fellow of the opposite side and to the anterior extremity of the first basibranchial of the branchial arch.

The basihyal (hypohyal, Kishinouye, 1923: 326; Allis, 1903: 138), is composed of two centers of ossification firmly united by a fine indentation. This indentation runs in a straight line in *cavalla* and *maculatus* but it is wave-like in *regalis*. The ventral ossification is the larger of the two and rests partly on the anterior lower process of the ceratohyal. The dorsal ossification bears at its upper interior corner a sharp process slightly curved backward.

The ceratohyal is the largest piece of the complex. It is broader at the posterior portion and its dorsal margin is slightly concave. Four branchiostegals rays are attached to respective articular surfaces at its ventral margin. The external surface of the ceratohyal is irregular and carries a slightly curved groove which lodges the arteria hyoidea, after that artery issues from the canal through the upper ossification of the basihyal (Allis, 1903: 140). The reverse holds true for the internal surface which is very smooth.

The anterior end of the ceratohyal bears a lower process, which, as has been pointed out above, joins the ventral ossification of the basihyal. The ceratohyal is partly united with the epihyal by means of a large indentation which projects from the external and internal margins of both bones and partly by the cartilage lying between them.

The epihyal is roughly triangular in shape and bears a posterior process to articulate the interhyal. Its ventral portion presents externally a sulcus to receive three branchiostegals rays. The groove of the arteria hyoidea, as in the ceratohyal, runs at the dorsal portion of the epihyal.

The interhyal is a small flattened bone which articulates the complex with the hyomandibular and symplectic, and is directed obliquely upward. Its posterior end is more or less pointed.

The remaining bone of the hyoid region, the urohyal (Plate VIII, Figs. 4-6) is elongated and medially located between the basihyals. Its posterior end is broad, pointed at the dorsal corner and embedded free in the muscular mass of the throat.

The bones of the hyoid complex are very similar and only minor differences were detected among the three species.

Branchial region.—The branchial arches (Plate XII, Figs. 1-3) are enclosed within the hyoid arch, with which they are connected at the

base. They support the gills and are composed of several series of bones. The general aspect of the branchial arches is very similar in the studied species and the following description is applicable to all three except for minor features which are noted below.

There are three basibranchials (Plate XIII, Figs. 1-6) which form a linear series along the median line. The second and third basibranchial bear deep oblique grooves on each side to receive the first and second hypobranchials, respectively. The first basibranchial is joined anteriorly to the glossohyal and laterally to the basihyals through intervening cartilage. The second is a little shorter than the first and is bent upward. The third basibranchial is the largest of the three, and is perhaps the more distinct of all. When viewed ventrally, it is decidedly broader in *maculatus* than in either *regalis* or *cavalla*.

The three hypobranchials are short bones which have their anterior ends thickened and form articular surfaces.

The ceratobranchials are very long, more or less curved and constitute the major support of the lower branchial arches. The ceratobranchials decrease in length from the first to the last but are similar in shape, except the fourth which is somewhat irregular at its anterior end. The ventral surfaces are deeply grooved their full length.

The epibranchials form a series of four irregular pieces of bone, which are the main support to the upper branchial arches. The fourth piece is the most internal and is very distorted, while the other three are rather straight and forked at their anterior ends.

The lower pharyngeals are modified ceratobranchials which bear a lamellar portion covered by a patch of villiform teeth. This lamellar portion is somewhat broader in *cavalla* than in the other two species.

The four upper pharyngeals are unequal in size and also bear fine teeth, except the first (suspensory pharyngeal) which is smooth. The suspensory pharyngeal connects posteriorly the branchial arches to the neurocranium. The remaining upper pharyngeals are more or less united to form a single plate.

At its external margin, the first branchial arch bears a series of gill rakers, which, although not forming part of the skeleton itself, are mentioned here because of their importance in the identification of *cavalla*, *maculatus*, and *regalis*. The gill rakers are more or less curved inward and carry two or three series of villiform teeth on their anterior surfaces. The number of gill rakers is quite variable among the compared species (Table 1).

The branchial arches are paved with two rows of dentigerous plates arranged on both sides of the median line and which bear fine villiform teeth.

PECTORAL GIRDLE

The pectoral girdle is formed of various bones connected with the neurocranium at the upper part through the posttemporal. The pectoral girdle supports the pectoral fin and is posteriorly bounded by the abdominal cavity.

The posttemporal (Plate X, Figs. 4-6) is a forked bone which affords the principal articulation of the pectoral girdle to the neurocranium. At its anterior end are two separated branches, one dorsal, the other ventral. The dorsal branch is concave at its upper side and lies on the epiotic. The ventral branch is shorter than the dorsal, and is directed antero-ventrally from the body of the bone; it articulates the median protuberance of the opisthotic and its anterior end is hollow. Both dorsal and ventral branches are connected by a thin lamina.

The main bulk of the posttemporal is roughly lanceolate in shape and its posterior margin is deeply notched. This notch is deeper in *maculatus* than in the other two species.

There is no indication of a scale bone in any of the specimens examined. However, due to the nature of the preparations and the presence of numerous enlarged scales in the region, the bone may have been overlooked.

The supracleithrum (Plate XI, Figs. 7-9) is a small ovate bone, more or less pointed at its anterior portion. The bone is considerably thickened at its lower edge, and rests on the dorsal wing-like extension of the cleithrum.

The supracleithrum is very similar in all three species, but it is somewhat more pointed at its posterior end in *regalis*.

The cleithrum (Plate X, Figs. 1-3) is a long curved bone which forms the greater part of the pectoral girdle. Its ventral portion is the largest and is folded back upon itself. This fold originates two walls, external and internal, which meet at their anterior margins and run parallel to each other.

The cleithrum is enlarged at its dorsal end in a wing-like extension, which is bent inward and receives the supracleithrum and the lower piece of the postcleithrum. In front of the wing-like extension a sharp process arises, which is directed forward and upward. The ventral end of the cleithrum is more or less pointed.



1



2



3



4



5



6

PLATE X. External view of right pectoral girdle (1-3), (cleithrum, scapula and coracoid). Dorsal view of left posttemporal (4-6). *S. cavalla*, 1, 4. *S. maculatus*, 2, 5. *S. regalis*, 3, 6.



1



4



2



5



3



6



7



8



9

PLATE XI. External view of right postcleithrum (upper piece, 1-3; lower piece, 4-6) and supracleithrum (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

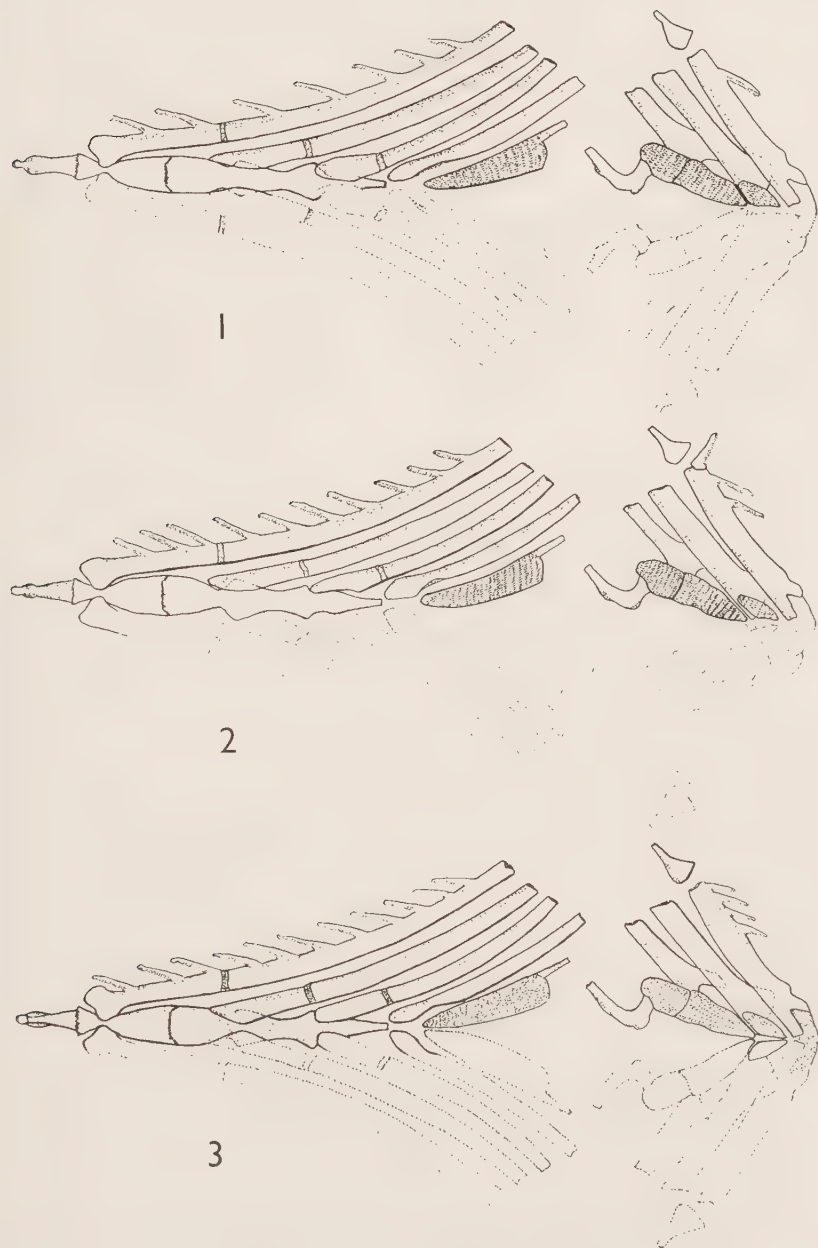


PLATE XII. Dorsal view of branchial arches (gill rakers indicated on outer arch).
1. *S. cavalla*. 2. *S. maculatus*. 3. *S. regalis*.

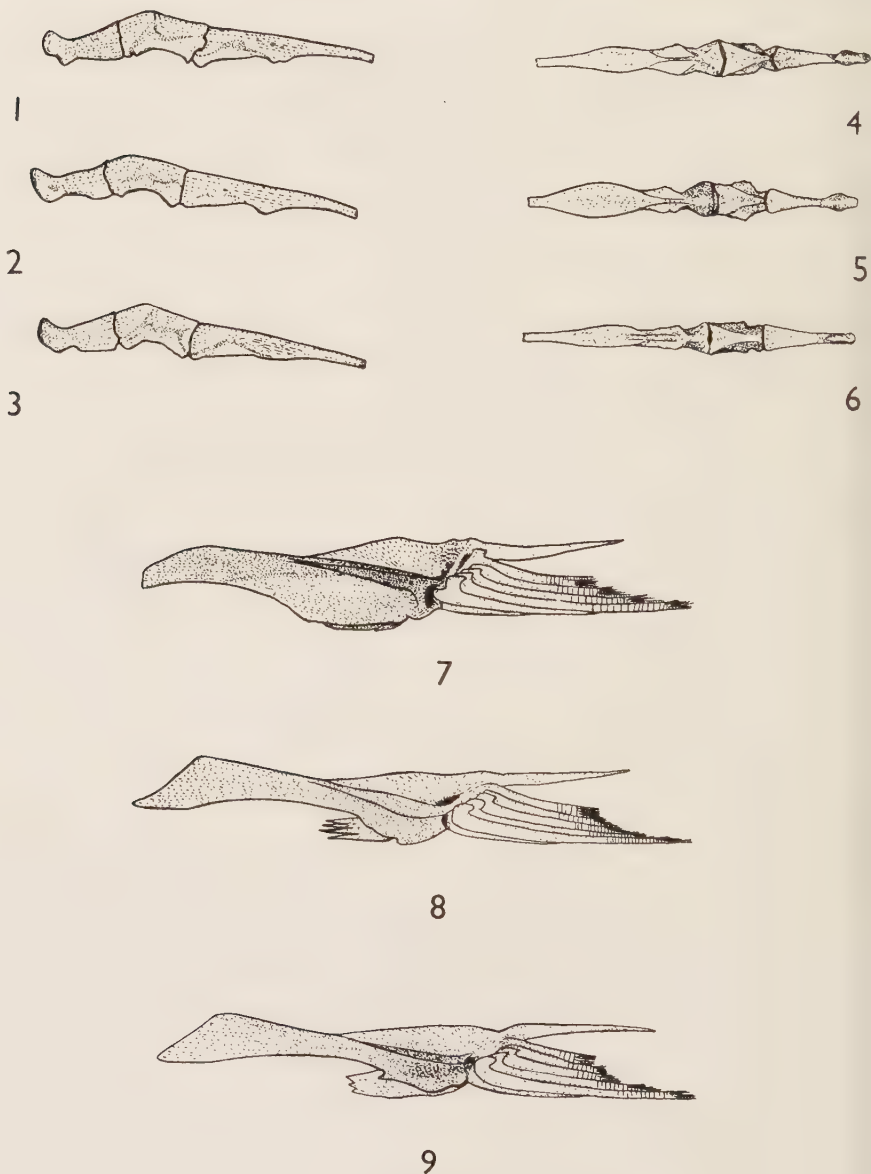


PLATE XIII. Lateral (1-3) and ventral (4-6) views of left basibranchials. Lateral view of left pelvic girdle and fin (7-9). *S. cavalla*, 1, 4, 7. *S. maculatus*, 2, 5, 8. *S. regalis*, 3, 6, 9.

At its internal surface, the cleithrum forms a large slit with the coracoid. This slit is located at the median region where both bones articulate and is almost rectangular in *regalis* while in *maculatus* and *cavalla* it is roughly triangular with the shortest side of the triangle forming its top.

The scapula (hypercoracoid, Kishinouye, 1923: 332) is a small bone connected to the cleithrum at the upper interior side (Plate X, Figs. 1-3). The scapula is pierced by a round foramen which is noticeably large in *regalis* and small in both *cavalla* and *maculatus*.

The scapula is posteriorly thickened to receive the four pterygials (actinosts basalia, branchial ossicles, Kishinouye, 1923: 333), which support the pectoral fin. These pterygials become larger as they meet the posterior margin of the scapula and the last one forms a foramen with the coracoid.

The coracoid (hypocoracoid, Kishinouye, 1923: 333) joins with the scapula above and anteriorly with the cleithrum (Plate X, Figs. 1-3). The coracoid is broad, more or less spear-shaped, and bears an external longitudinal sulcus closed to the anterior margin.

The postcleithrum is divided into two thin portions (Plate XI, Figs. 1-6). Both are elongated and bent. The lower piece has an anterior pointed process which is narrower in *maculatus* than in the other two species. The posterior process is relatively broad and straight.

PELVIC GIRDLE

The pelvic girdle (Plate XIII, Figs. 7-9) is composed of a pair of thin plates united at the median line, the "public" bones (Günther, 1880: 59). These bones are embedded free in the flesh of the abdominal wall and each one consists of three portions: anterior external, anterior internal, and styliiform (Kishinouye, 1923: 334).

In the genus *Scomberomorus* the largest portion is the anterior external which is long and almost straight. The styliiform process is more or less large. In *cavalla* the anterior external portion is somewhat broader than in the other two species.

There is one spine and five soft rays in the pelvic fin. The rays are visibly striated at their tips and firmly bound together.

VERTEBRAL COLUMN

The vertebral column (Plate XIV, Figs. 1-3) of *Scomberomorus* exhibits a remarkable simplicity if we compare it with one of the other scombroids. The haemal and neural processes are "more slender,

fragile and fibrous than in any other genus of the Scombridae" (Starks, 1910: 90).

The vertebrae are more or less short, particularly at both extremities of the backbone. Each vertebra has six longitudinal grooves: ventral median, dorsal median, and two pairs of laterals. The penultimate vertebra coalesces with the hyural plate and is considerably reduced.

The total number of vertebrae is quite variable in the three species, ranging from 42 to 53. *S. maculatus* has 52 or 53 vertebrae, *cavalla* has 42 or 43, and *regalis* comes between the two with a count of 47 to 49.

The vertebral column may be divided conveniently into precaudal (abdominal) and caudal portions. The first caudal vertebra is that which possesses an elongated haemal spine. This spine occurs at the 18th or 19th vertebra in *cavalla*, at the 20th or 21st in *regalis*, and from the 22nd to the 24th in *maculatus*.

I follow the suggestions of Conrad (1938: 12) in dividing the two primary regions of the backbone into six other secondary regions: postcranial, mesabdominal, postero-abdominal, antero-caudal, tail segment, and hypural complex. The six regions have the following characteristics:

1. The postcranial vertebrae bear stout neural arches and spines. There are six vertebrae of this kind in each species.

2. The mesabdominals follow the postcrania, bear ribs, but do not possess haemal arches.

3. The postero-abdominals have closed haemal arches and bear ribs.

4. The antero-caudals greatly resemble the postero-abdominals except that they have lost the ribs and have developed haemal spines.

5. In the tail segment, the vertebrae have their neural and haemal spines entering into the support of the caudal fin.

6. The hypural complex is an almost symmetrical fan which receives the rays of the caudal fin.

The postcranial region is composed of six vertebrae which are obviously stouter than the vertebrae of the following region. The first vertebra or "atlas" is reduced in size, autogenous, ankylosed to the neurocranium, and bears no rib. The second vertebra also does not bear ribs but the third bears both a pleural and an epipleural rib. The

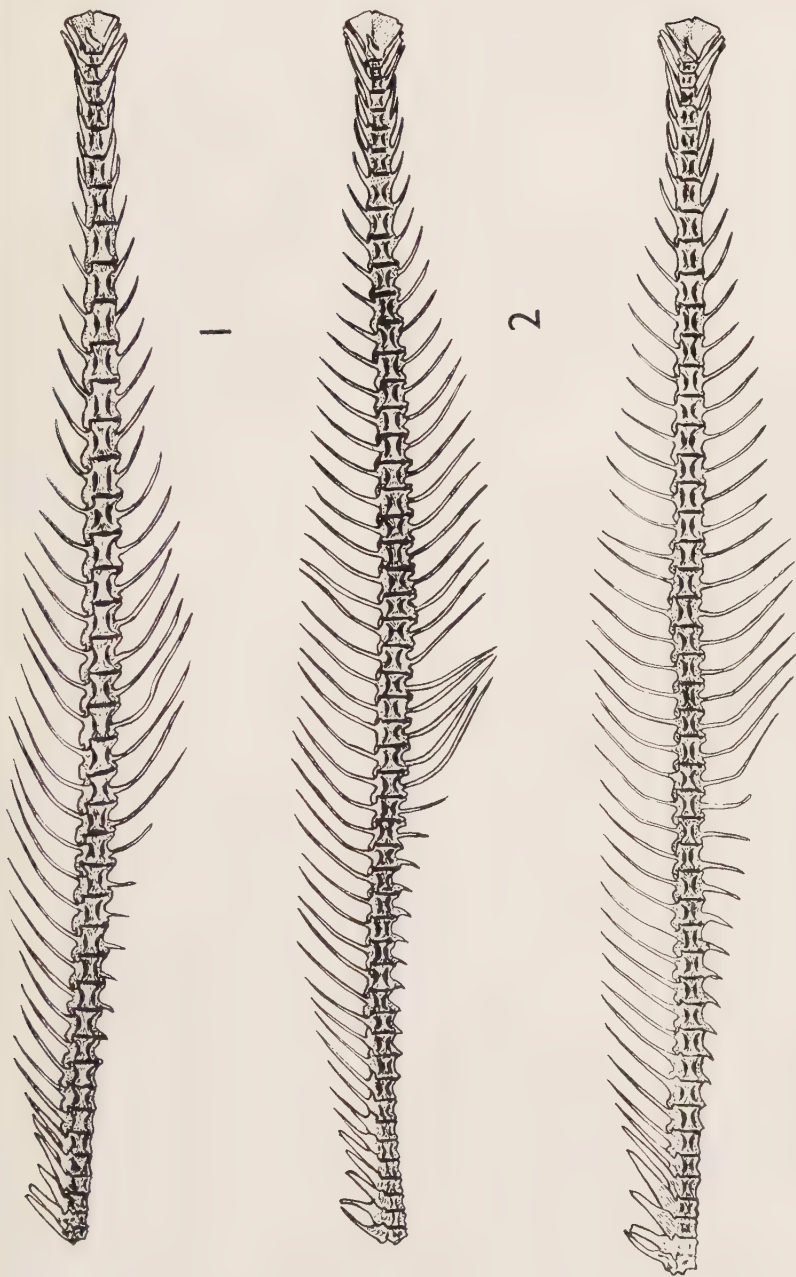


PLATE XIV. Lateral view of vertebral column, 1. *S. cavalla*,
2. *S. maculatus*, 3. *S. regalis*.

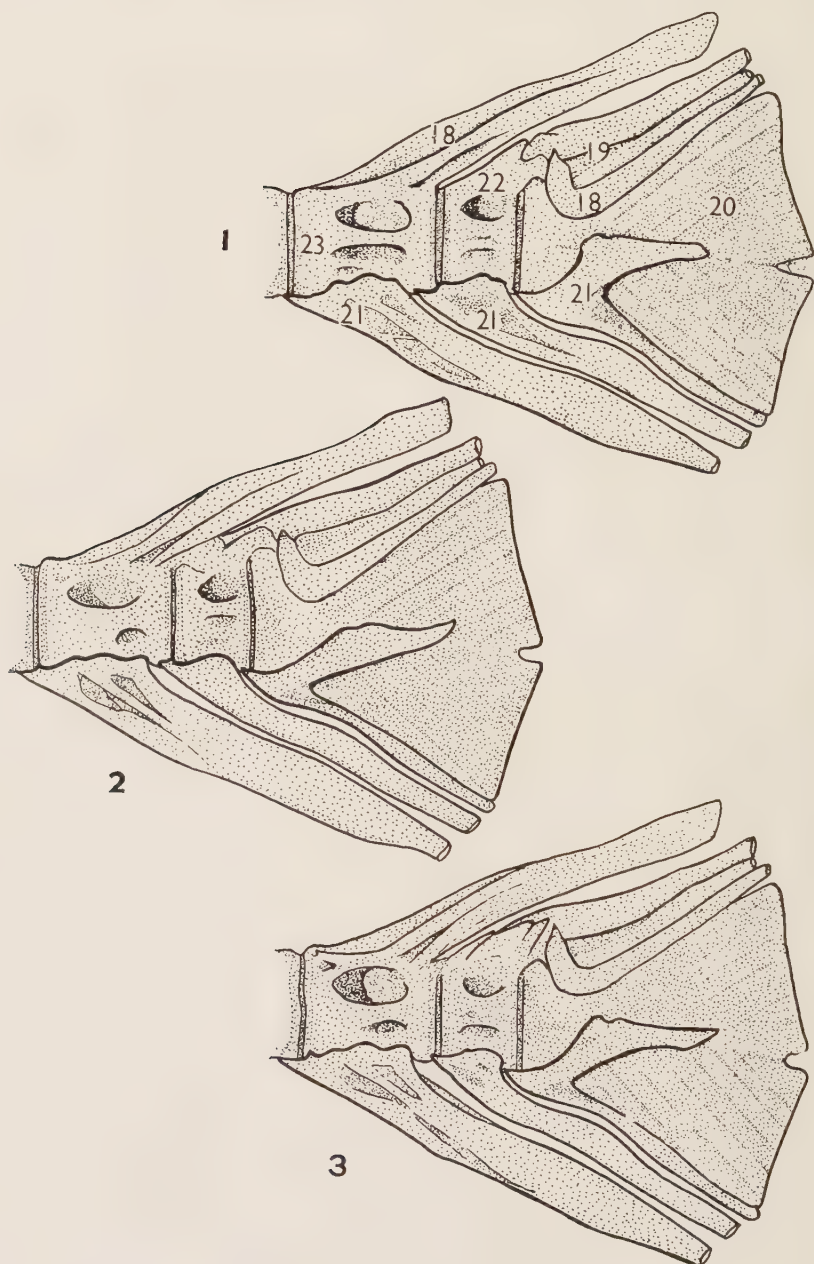


PLATE XV. Lateral view of hypural complex. 1. *S. cavalla*.
2. *S. maculatus*. 3. *S. regalis*.

pleural and epipleural ribs form dorsolaterally the boundaries of the abdominal cavity.

All of the mes- and postero-abdominals have ribs and more or less strongly developed pre- and post-zygapophyses. As in *Acanthocybium*, a postero-inferior zygapophysis develops, starting at the eight vertebra. According to Conrad (1938: 13), this postero-inferior zygapophysis arises from the bony septum between the lateral grooves of the centrum in the anterior abdominals, but as the centra deepen and the ventral grooves become more pronounced, the posterior haemal zygapophyses move to the ventral border of the ventral groove. In the more anterior abdominals this zygapophysis may serve to stiffen the column.

Parapophyses can be unmistakably noticed at the third vertebra. From that vertebra backward they become larger until they finally meet (haemapophyses) to form a closed haemal arch. This closed haemal arch occurs at the 10th vertebra in *cavalla*, at the 12th in *regalis*, and from the 13th to the 15th in *maculatus*.

On the first 7 or 8 closed haemal arches no spines are present, but on the arch of the first antero-caudal the spine is long and similar to the next.

The antero-caudal vertebrae are similar to the postero-abdominals, except that the haemal arch bears a spine and the ribs disappear.

Applying the terminology used by Whitehouse (1910:592), Hollister (1936:258), and Ford (1937:3), we may describe the tail segment and hypural complex of *Scomberomorus* as follows: the tail segment is composed of three vertebrae which enter into the support of the caudal fin. The antepenultimate bears an epural and an autogenous hypural (hypural 1); i.e., it is closely applied to but definitely not fused with the vertebral centrum, (Ford, 1937:3). The penultimate has both an epural and a hypural (hypural 2) which is also autogenous. The terminal vertebra bears a hypural (hypural 3), which develops a hook-like projection directed a little upward. The vertebra also supports the hypural plate which is formed by the fusion of several hypurals and constitutes a complex by itself. The hypural plate is a nearly symmetrical fan-shaped structure with a prominent notch at the mid-point on its posterior margin. The bases of the caudal rays overlap the edge of the hypural plate and obscure the notch.

The urostyle is greatly reduced and completely fused with the hypural plate, this condition being indicative of a high degree of specialization. There are two dorsal caudal radials between the last

epurals. These dorsal caudal radials are not directly connected to the vertebral column.

The tail segment and hypural complex (Plate XV, Figs. 1-3) are very similar in all the three species, but the hook of the third hypural is somewhat different, being higher in *maculatus* than in the other two species. This difference, however, seems insufficient for separating the species.

In form and arrangement the hypural complex of *Scomberomorus* resembles that of *Acanthocybium*, except a) that hypurals are auto-genous in *Scomberomorus*, while in *Acanthocybium* they are attached to their respective vertebral centra (Conrad, 1938:16), and b) that *Scomberomorus* has only two dorsal caudal radials while there are three in *Acanthocybium*.

RELATIONSHIPS WITHIN THE GENUS *Scomberomorus*

The skeletons of *cavalla*, *maculatus*, and *regalis* are very similar, in general. *S. maculatus* and *regalis* appear more similar to each other than is either to *cavalla*, a relationship corroborated by external features. There is no question that the three are quite distinct species. (A synopsis of meristic and skeletal differences is presented in Tables 1 and 2).

Although there were numerous similarities in the shape of the bones and the position of depressions, grooves, apophyses, etc., a number of reliable differences could be chosen. These differences are arranged in the following key, which will separate those species discussed in this paper. Only five specimens of *regalis* were available, but in view of the slight infraspecific variation exhibited in the larger series of *cavalla* and *maculatus*, the differences shown by *regalis* seem trustworthy.

OSTEOLOGICAL KEY TO THE GULF AND CARIBBEAN SPECIES OF THE GENUS *Scomberomorus*

- A. Temporal ridge straight or slightly convex and not prolonged posteriorly. Vomer thick and somewhat pointed. Separation between alisphenoids narrow. Median anterior projection of basisphenoid broad, not needle-shaped. Total number of vertebrae 42 or 43. Parasphenoid relatively broad, concealing the brain chamber opening.

Scomberomorus cavalla

- AA. Temporal ridge concave and prolonged posteriorly. Vomer thin and spatulate. Separation between alisphenoids broad. Median anterior pro-

jection of basisphenoid needle-shaped. Total number of vertebrae 47 to 53. Parasphenoid narrow, leaving the brain chamber opening exposed.

B. Total number of vertebrae 52 or 53. Scapular foramen small.

Scomberomorus maculatus

BB. Total number of vertebrae 47 to 49. Scapular foramen large.

Scomberomorus regalis

Examination of similarities and differences among the species indicates that *regalis* seems to be intermediate between *cavalla* and *maculatus*, although much closer to the latter. This conclusion is largely based on the vertebral count, point of occurrence of the first closed haemal arch and the first haemal spine (Table 1). There is a considerable gap between vertebral counts and this affords a striking difference because the vertebral counts of mackerels show little variation (Ford, 1937:30). *S. maculatus* and *regalis* form a compact group which contrasts with *cavalla*.

TABLE 1
MERISTIC CHARACTERISTICS OF THE FLORIDA SPECIES
WITHIN THE GENUS *Scomberomorus*

Character	<i>cavalla</i>	<i>maculatus</i>	<i>regalis</i>
Total number of vertebrae	42-43	52-53	47-49
First closed haemal arch at vertebra number	10	13-15	12
First haemal spine at vertebra number	18-19	22-24	20-21
Dorsal spines	15-16	16-18	16-18
Dorsal rays	16-17	15-18	16
Dorsal finlets	8-9	8-9	8-9
Anal spines	2	2	2
Anal rays	14-17	15-17	14-15
Anal finlets	8-10	8-9	8
Gill rakers upper limb	1	2-3	3-4
Gill rakers angle	1	1	1
Gill rakers lower limb	6-7	10-12	11-13
Gill rakers total	8-9	13-15	15-18

It is important to note here the external features that strengthen these conclusions. In *maculatus* and *regalis* the lateral line slopes gradually ventrad under the second dorsal fin while in *cavalla* it dips sharply downward followed by a lesser rise and fall, a characteristic feature. The juveniles of all three are spotted, but large *cavalla* are

TABLE 2

A SYNOPSIS OF DIFFERENTIAL CHARACTERISTICS FOR *Scomberomorus cavalla*, *S. maculatus*, AND *S. regalis*
 (* Indicates that *regalis* is similar to *maculatus*)

Character	<i>cavalla</i>	<i>maculatus</i>	<i>regalis</i>
1. Temporal ridge	Straight or slightly convex. Not prolonged posteriorly.	Concave. Prolonged posteriorly.	*
2. Auxiliary ridge	Low	High.	*
3. Vomer	Thick and somewhat pointed	Thin and spatulate.	*
4. Frontals	The slit (pineal window) at the level of alisphenoids. Conspicuous.	The slit (pineal window) inconspicuous and carried a little forward from the level of alisphenoids.	*
5. Alisphenoids	Slightly separated at the median line. Brain chamber opening relatively small.	Widely separated at the median line. Brain chamber opening relatively large.	Widely separated at the median line. Brain chamber opening very large.
6. Parasphenoid	Broad. The median keel not forming a cutting-edge.	Narrow. The median keel forming a cutting-edge.	*
7. Basisphenoid	Median anterior process broad. Not needle-shaped.	Median anterior process needle-shaped.	*
8. Hyomandibular	Lamella broad.	Lamella narrow.	*
9. Scapula	Foramen small.	Foramen small.	Foramen very large.
10. Pelvic girdle	Anterior external portion broad.	Anterior external portion narrow.	Anterior external portion narrow.
11. Vertebral column	First closed haemal arch occurring at vertebra number 10. First haemal spine at vertebra 18th or 19th. Total number of vertebrae 42 or 43.	First closed haemal arch occurring at vertebra number 13 to 15. First haemal spine at vertebra 22nd to 24th. Total number of vertebrae 52 or 53.	First closed haemal arch occurring at vertebra number 12. First haemal spine at vertebra 20th or 21st. Total number of vertebrae 47 to 49.

unmarked whereas *maculatus* retains its spots and *regalis* has numerous yellow dashes on its sides. *S. cavalla* attains a much larger size than either of the other two species (Florida averages: *cavalla* 5 to 8 lbs., schools of juveniles, solitary to 40 lbs.; *maculatus* 2 to 2.5 lbs., 4 lbs. not unusual; *regalis* 3 lbs.)

Similarly, differences exist in numbers of gill rakers and dorsal spines (Table 1), *regalis* being closer to *maculatus* in each instance.

Since I was unable to examine Pacific specimens, I draw upon the work of Clothier (1950:53), which involves analyses of several individuals, for comparative data. Thus, checking his vertebral counts, it was found that *S. sierra* Jordan and Starks had 47 to 49 vertebrae, the first haemal arch occurring at vertebra 12th to 14th and the first haemal spine at vertebra 21st or 22nd. *S. concolor* (Lockington), had 47 or 48 vertebrae, the first haemal arch occurring at vertebra 12th or 13th while the first haemal spine occurred at vertebra 20th or 21st. Both species exhibit the characteristics of the vertebral column of *S. regalis*, particularly in the total vertebral count (Table 3).

TABLE 3

Meristic Characters of the Genera *Scomberomorus*, *Cybiium* and *Acanthocybiium*

Species	Characters						total number of vertebrae
	dorsal spines	dorsal rays	dorsal finlets	anal rays	anal finlets	gill rakers total	
<i>S. cavalla</i>	15-16	16-17	8-9	14-17	8-10	8-9	42-43
<i>S. regalis</i>	16-18	16	8-9	14-15	8	15-18	47-49
<i>S. maculatus</i>	16-18	15-18	8-8	15-17	8-9	13-15	52-53
<i>S. sierra</i>	16-18	15-18	8-9	15-18	8-9	?	47-49
<i>S. concolor</i>	16-17	16-18	8	16-20	7-8	?	47-48
<i>C. commersoni</i>	17	15	9	14	9	3	44
<i>S. chinense</i>	16	15	8	16	7	11	40
<i>S. guttatum</i>	16	19-20	8-9	21	8	10	51
<i>S. koreanum</i>	14	19-21	9	18-21	7	13	46
<i>S. nipponium</i>	19	15	9	15-17	8	12-13	50
<i>A. solandri</i>	26	11	9	11	9	0	54-64

Five western Pacific species of *Cybiium* described by Kishinouye (1923:415-424) provide interesting comparisons. The generic name *Cybiium* is based on *C. commersoni* (Lacepede) which is the most externally marked species of the group. In many features it appears to form a link between the *cavalla* group of *Scomberomorus* and *Acanthocybiium* and perhaps merits generic treatment. The other four

species (*guttatum*, *niphonium*, *koreanum* and *chinense*) appear generically indistinguishable from *Scomberomorus* on the basis of Kishinouye's (1923) descriptions. Munro (1943) placed all the species of *Cybium* including *commersoni* in *Scomberomorus*.

Like *maculatus* and *regalis*, *guttatum*, *niphonium*, and *koreanum* have a gently sloping lateral line and a spotted pattern, but have a dorsal-spine and gill raker counts variously intermediate between those species and *cavalla*. *S. chinense*, a large species, has a lateral line similar to that of *cavalla* and lacks a spotted pattern. Its counts agree closely with those of *cavalla*. Of the four western Pacific species mentioned only *chinense* has the low vertebral count of *cavalla*.

Further study may show that the differences noted here between *cavalla* on the one hand and *maculatus* and *regalis* on the other, hold on a world-wide basis and suffice to divide *Scomberomorus* into two subgeneric units. Although the writer has not seen the Pacific species, it is suggested that *chinense* belongs to the *cavalla* group while *guttatum*, *niphonium*, and *koreanum* represent the *maculatus-regalis* complex. *Cybium commersoni* would appear to be intermediate between *Scomberomorus* (the *cavalla* group) and *Acanthocybium*.

RELATIONSHIPS WITH OTHER GENERA

It is presumptive to discuss the relationships of the genus *Scomberomorus* with other genera of the Family Scombridae, without a thorough knowledge of all the species. However, I shall attempt to present those remarks pointed out in the current literature on scombroids.

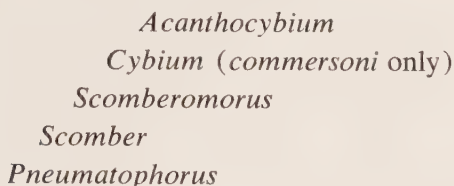
The problem of relationships among the family Scombridae has been treated several times since that of Regan (1909). Starks (1910), Gregory (1933), and Conrad (1938) published some speculations about probable relationships based mainly on cranial characters.

Starks (1910:77) says that "though the Scombridae does not contain the most primitive of the scombroids, it has served as a center around which the more or less aberrant forms have been arranged." Later in the same paper (p. 80) he says "certain characters indicate that *Scomberomorus* has come more directly from the Scombrinae than have any other of the genera, though its evident alliance with *Acanthocybium*, an aberrant form, shows how far it has departed from the *Scomber* type."

Kishinouye (1923:294) and later Berg (1947:483) have placed the genus *Scomberomorus* in the Family Cybiidae, but we have here

accepted the well-known classification of Jordan, who puts the genus *Scomberomorus*, together with *Acanthocybium* and *Scomber*, in the Family Scombridae.

Comparisons with the skeletal descriptions of *Scomber* (Allis, 1903), *Acanthocybium* (Conrad, 1938) and *Pneumatophorus* (Godsil, 1954) have lead the writer to believe that the following diagram might be indicative of relationships.



It is assumed that *Scomberomorus* is very closely allied to *Acanthocybium*, particularly in the following characters.

1. The nasals do not project beyond the dermethmoid.
2. The temporal ridge is carried forward by the frontals.
3. Arrangement of cranial ridges.
4. Suborbital ring rudimentary and mingled by surrounding scales.
5. Basic plan of vertebral arrangement.
6. Presence of dorsal caudal radials in the tail segment.

Differences between *Scomberomorus* on the one hand and *Pneumatophorus* on the other are more marked than those between *Scomberomorus* and *Acanthocybium*, particularly in the following characters:

1. Temporal ridge not carried forward to the dermethmoid.
2. Depth of neurocranium.
3. Pterotic prolonged posteriorly in an elongated spine.
4. Suborbital ring complete.

Notwithstanding these differences, all the genera seem to depart from a common scombroid type, which is perhaps better typified by *Scomber* than by any other genus.

SUMMARY

A study of the osteology of the Florida species of the genus *Scomberomorus* substantiates the work of previous authors in separating them into three distinct species.

Comparison of the three species, *cavalla*, *maculatus*, and *regalis*, demonstrates that *cavalla* stands apart from the other two species in a series of features which they share. *S. cavalla* is regarded as the more primitive of the three species studied.

It is suggested that these two species groups exist on a world-wide basis, western Pacific forms being assignable to one or the other complex.

The limited number of specimens examined and the time available for this work precluded a more thorough study.

The visceral anatomy needs to be subjected to a similar study.

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A WOOD INCUBATION METHOD FOR THE STUDY OF LIGNICOLOUS MARINE FUNGI^{1,2}

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ABSTRACT

Test panels of wood, submerged in various marine localities, often show little or no visible lignicolous fungal development during the initial laboratory examination. Through a process of controlled incubation of the fungal infested wood, using sterilized glass chambers, the incipient fungal infestation develops the characteristic morphological features of the various marine ascomycetous and deuteromycetous species present. Thus, the time of the attack upon the submerged wood can be determined more readily. For, while the environmental conditions or the stage of physiological development of the organism may not have been favorable for the maturation of the diagnostic reproductive structures, such fructifications develop vigorously under the incubation conditions.

INTRODUCTION

Since the work of Barghoorn and Linder (1944), investigators of marine fungi have become cognizant of a diverse fungal flora vigorously colonizing submerged wood. The intrinsic value of studies of these organisms is apparent, serving to elucidate their specific biological processes and their participation in numerous marine activities. Becker, *et al.* (1957), Meyers and Reynolds (1957), and Schafer and Lane (1957) have discussed and presented various evidences for the existence of possible relationship between lignicolous marine fungi and associated wood attacking animals. Further studies bearing on the role of these fungi in wood degradating processes are indicated. As such investigations develop, it is imperative to have accurate tabulations of the fungal infestation during all stages of attack.

In our earlier studies of the distribution of lignicolous marine fungi (Meyers, 1954), it was observed that fungal infested wood often showed further marine fungal development, even after a period of several weeks in our laboratory. Frequently, the genera and species that developed in this subsequent period were not found during the initial microscopic examination of the material. These dissimilarities in the pattern of initial and later infestation on the same wood specimens suggested the possible importance of this continuous fungal growth in our work. This laboratory procedure discussed here, in conjunction with our other analytical tests, permits a more complete

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definitive approach to the tabulation of the marine fungi on and within the wood.

METHODS

In our tests, we have used sets or traps of basswood and southern yellow pine, composed of four to six panels, arranged in a "sandwich-like" manner. The wood pieces, approximately 2 x 5 x $\frac{1}{4}$ - $\frac{1}{2}$ inches, are separated from one another by a distance of $\frac{1}{8}$ to $\frac{1}{4}$ inch, using brass washers as dividers. The entire unit of panels is held together with a brass machine screw, with usually six to eight such sets attached by brass screw eyes to a single "Kordite" sash cord. This arrangement of the wood permits the exposure of a maximum number of surfaces for fungal colonization and sporulation. The development of fouling organisms and the abrasive action of sea water usually is heaviest on the outer wood surfaces. Thus, even over an extensive exposure period, the inner panels can still be examined effectively for fungal infestation.

The numerous scientific and naval personnel cooperating in this program have been provided with a set of instructions outlining the exposure and collection methods. Special waterproof heat-sealed bags (MIL-36, Cadillac Products, Inc., Ferndale, Michigan) are used for the return of the wood to our laboratory. The wood is placed within these bags after its removal from the water. Shipment is usually the same or the following day. Water temperature and other hydrographic data of the test site are sent to us with each shipment. The transit period varies from several days to one week, depending on the particular locality. For instance, wood shipped via air mail and parcel post from Kodiak, Alaska, and St. Andrews, New Brunswick, the northern extremities of our survey, arrives within one week, while wood from Key West, Florida, is received the day after its collection.

The sets of four to six panels are not disassembled until the wood is received in our laboratory. By keeping each set intact during collection and shipment, the opportunity for contamination by aerial fungi on the inner wood surfaces is lessened. In our experience, the incidence of such contamination has been negligible. When present, these adventitious fungi can readily be distinguished from the morphologically characteristic and regularly occurring marine species. In most of our test sites, the amount of fouling organisms on the inner surfaces is slight compared to that often present on the outer wood surfaces. Hence, we have found that scraping of the inner surfaces usually is not necessary.

Following removal of the wood from the shipping bags, the individual panels sets are disassembled, and the wood pieces placed in alcohol-sterilized pyrex trays ($11\frac{3}{4} \times 7\frac{1}{2} \times 1\frac{3}{4}$ inches), one inverted over the other. This glass chamber is not sealed immediately, but is left ajar, approximately one inch, to allow evaporation of surface moisture from the wood. A drying period of two to three days at room temperature, or at slightly higher temperatures, 30 to 32°C, is sufficient to remove the excess surface water. Occasionally, water accumulates in the lower tray and must be decanted. This initial drying period is an essential part of the incubation process, for subsequent fungal development and sporulation does not occur when thoroughly wet wood is sealed in the chamber. We have selected fairly arbitrary criteria to determine the proper moisture conditions of the wood for incubation. Among such criteria are, development of aerial hyphae from the wood surface, exudation of spore masses from perithecia present, and microscopic examination. In the latter process, an inoculating needle is drawn across the surface of the wood to note the relative dryness of the outer tissues. For maximum fungal development, the wood surface should be air dry, while the interior of the panels is still saturated, as indicated by the exudation of water when the wood is pressed with the needle.

After air drying, the pieces are then re-examined to tabulate the initial fungal flora present and to transfer spores and mycelial growth to nutrient media for later cultural studies. If perithecia are present, they can be recognized on the air dry wood more readily. Cirri of spores from perithecia, especially in *Lulworthia* and *Ceriosporopsis*, facilitates the transfer of these ascomycetous genera to pure culture. Similarly, the development of aerial conidia of *Helicoma*, *Trichocladium*, *Piricauda* and other deuteromycetous genera, enhances the identification and isolation of these fungi.

It is necessary to check *each* wood panel, since noticeable variation in number and in concentration of fungal genera and species occurs among the wood pieces on the same set. After the initial examination, the pyrex trays containing the wood are sealed together with cellophane tape, and the chamber incubated at room temperature, approximately 20 to 25°C.

The length of incubation is variable, from one to as long as 10 weeks, depending on the initial condition of the wood and on the rate at which fungal growth develops. We have found that the average effective incubation period is usually three to four weeks. At least several

microscopic examinations of the wood are made during incubation. A few paradichlorobenzene crystals are added to each chamber to prevent possible attack by mites.

RESULTS AND DISCUSSION

Variation in the cultural environment, using controlled humidity and temperature chambers, is commonly applied in mycological and plant pathological work to stimulate microbiological development. Studies of the infection of plant material (Riker and Riker, 1936), of deterioration processes (Siu, 1951), and of the growth of various groups of fungi (Wehmeyer, 1952; Alexopoulos, 1953), all incorporate incubation techniques into their methodology. Often, these techniques elucidate the interrelationships between the various microbiological genera and species colonizing the host or substrate. In most instances, such methods are a valuable adjunct to field studies.

Pyrex kitchen trays have been used by other workers (Hutner, *et al.*, 1953; Vishniac, 1958) as sealed incubation chambers for physiological studies of pure cultures of microorganisms. These chambers permit the organisms to develop under conditions of uniform humidity, free from chance contamination and excessive evaporation of the culture medium.

The presence or absence of fungal reproductive bodies is the main criterion used to establish infestation. However, wood without evident sporulation on or in the outer wood tissues, should not be assumed to be free from fungal attack. In our earlier work (Meyers, 1954), the tabulation of fungal attack did not include potential or immature sporulation nor the actual extent of mycelial ramification within the wood.

Our present investigations show that the mycelia of various marine genera and species may be rampant throughout the wood, while environmental conditions or the stage of physiological development of the organism may inhibit or prevent the maturation of the reproductive organ. A large number of the panels from various localities received in our laboratory, showing little or no initial fungal growth, have developed considerable populations of marine fungi during incubation.

Many of the fungi isolated during the incubation process are marine species of Fungi Imperfecti, several of which appear to be genera and species new to science. Two deuteromycetous species, representative of *Trichocladium* and a fungus placed in the genus *Graphium*, on

wood exposed mainly in subtropical and temperate waters, show reproductive development during incubation. Wood submerged at northern and boreal stations, especially in the winter months, exhibits excellent sporulation of *Piricauda pelagica* Johnson and other genera and species of Moniliales over the incubation period. Usually, the principal genera of Fungi Imperfecti developing during incubation on wood collected in boreal localities, i.e., Alaska, Newfoundland and Nova Scotia, differ from those present on wood submerged in warmer littoral areas.

The ascomycetous genera, *Lulworthia*, *Peritrichospora*, *Ceriosporopsis* and *Halosphaeriopsis*, readily produce mature perithecia on wood in the culture chamber. The two former genera are especially abundant.

The effectiveness of incubation is demonstrated in our extensive studies of wood exposed in northern localities during the winter months. At Halifax, Nova Scotia, and at Kodiak, Alaska, basswood panels submerged for as long as 56 and 88 days, respectively, showed only mycelial development in our initial examination. No perithecia or conidia were observed. However, considerable sporulation occurred on the wood after incubation for several weeks. The wood exposed at Halifax showed numerous fructifications of two ascomycetous genera, *Peritrichospora* and *Ceriosporopsis*, while panels from Kodiak exhibited perithecia of *Halosphaeriopsis*. The conidia of at least two deuteromycetous genera developed on the wood from both localities. Subsequent collections of wood exposed in these areas for longer periods showed on initial examination, the same ascomycetous and deuteromycetous genera that had developed during incubation on wood of earlier tests.

The use of the incubation technique as an analytical approach to the study of wood infestation by marine fungi is essential to a more adequate knowledge of the various units of the fungal populations. Vegetative growth can develop the diagnostic reproductive stage. Maturation and further development of reproductive organs may occur. Spore production and discharge facilitates pure culture work. Finally, the pyrex chamber method permits storage of newly received wood, free from laboratory contamination, until a thorough examination can be made of the viable fungal growth.

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MISCELLANEOUS OBSERVATIONS ON THE BEHAVIOR OF CAPTIVE SEA TURTLES

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ABSTRACT

The behavior of 4 species of sea turtles which were observed for four and one half months in the tanks at Marineland, Florida is reported. The turtles were not aggressive, showed definite respiratory patterns, and exhibited varying degrees of territoriality. Feeding, sleeping, swimming, and other behavior characteristics are discussed.

INTRODUCTION

There is little available information on the behavior of adult sea turtles other than that concerning their activities during mating (Wood, 1953) and egg-laying (Ingle and Smith, 1949; Carr, 1952). The writer was encouraged by Mr. F. G. Wood, Jr., Curator, Marineland Research Laboratory, Marineland, Florida, to present the following admittedly incomplete observations as a possible stimulus to further work, and as possible explanations for some of the behavior of wild individuals.

Despite the fact that individual sea turtles have been kept in various zoological gardens and aquaria for as long as 15 years (Flower, 1925, 1937; Loveridge, 1945), the only report on their general behavior, except for occasional comments scattered through the literature, is one by Layne (1952). He studied the behavior of three individuals of the Atlantic loggerhead turtle, *Caretta c. caretta* (Linné), which had an average carapace length of 15 inches (38.2 cm), and he described briefly their temperaments, manner of resting, territoriality, diets and respiratory rates.

The present observations were made from September 20, 1953, through February 12, 1954, on the sea turtles at Marine Studios, Marineland, Florida. The turtles were kept in two large tanks. One was circular and contained 400,000 gallons of sea water; the other, roughly rectangular in shape, contained 450,000 gallons. The water in the two tanks was continuously changed, and both tanks were abundantly supplied with portholes to facilitate observations. The temperature in the rectangular tank was rarely allowed to drop below 20°C, although the temperature in the circular tank fluctuated with seasonal changes in the ocean from 17°C-27°C.

The populations of the two tanks were somewhat diversified, as the following enumeration indicates. The circular tank contained the following turtles: 9 Atlantic loggerheads (6 females, 3 males); 2 female Atlantic ridleys, *Lepidochelys kempi* (Garman); and 2 Atlantic green turtles, *Chelonia mydas mydas* (Linné) (1 female, 1 male). In addition, this tank held the 10-13 members of a porpoise colony and several hundred triggerfish, grunts, snappers, groupers, and other bottom-dwelling fishes. The rectangular tank contained the following chelonians: 9 Atlantic green turtles (4 females, 2 males, one adult with kyphosis which concealed its secondary sex characters, and 2 immature specimens); 5 Atlantic hawksbills, *Eretmochelys imbricata imbricata* (Linné) (4 females, 1 male); and 2 female Atlantic ridleys. In addition, this tank contained about 75-100 species of Florida marine fishes, totaling approximately 2,000 individuals. All the turtles with the exception of the two immature green turtles had been at Marine Studios since 1946 or 1947. Measurements of several individuals appearing average in size placed them near the maximum sizes given by Carr (1952).

During a period of renovation, the animals were moved temporarily to different tanks. This transfer proved instructive, because it provided a means of comparing the behavior of the same individuals under slightly different conditions.

This study would not have been possible without the generous cooperation of the staff of Marine Studios and of its Curator, Mr. F. G. Wood, Jr. The author is also indebted to Dr. William N. Tavolga, Dr. Margaret Tavolga, and Dr. C. D. Beers for much valuable assistance.

DISCUSSION

Temperament. The turtles seldom showed signs of aggressiveness, although they were occasionally pushed away by a diver during a feeding program. On one occasion two female hawksbills were observed in the act of fighting for a short period—perhaps over food—and it was not uncommon for one turtle to bite another when regaining a resting place. Such bites were of a characteristic type. The turtle bitten was never observed to fight back, but always left the resting spot immediately. Presence or absence of a social hierarchy was not established in this study although there was some indication that one was present in both tanks.

Layne reported that his individuals were "quite docile" and that they "attempted to bite each other only during the excitement of

feeding or when one attempted to usurp the resting site of another." Hildebrand and Hatsel (1927) reported the loggerheads kept by them as being docile at first, but later becoming so extremely vicious that they had to be released.

Diet. The turtles in the circular tank were fed squid regularly and fish scraps twice a week. Occasionally one of the specimens would feed on articles dropped into the tanks by careless visitors. The turtles in the rectangular tank were fed fish as well as cabbages which were tied to the bottom. No estimates of the amount of food eaten by an individual were available. Layne fed his loggerheads "a variety of dead fish, dead squid, spoiled lobster meat, soft parts of mussels, whelks, and various other mollusks."

Feeding behavior. The maneuvering of food by the forelimbs, which is so characteristic of hatchlings (Pope, 1939) and land turtles, was observed only once in the adults. When eating, a turtle swam or crawled to a distance of about 10 cms from a morsel, then after a short pause, thrust its head straight forward and snapped at the food. Food was worked to the back of the mouth by opening the mouth and thrusting the head forward. They were also observed to open their mouths and let either eddy currents or some unidentified force move the food to the back of the mouth. Although the turtles frequently tilted their heads while feeding, the snaps were always straight forward. Since the tongue is fixed immovably to the floor of the mouth (Carr, 1952), this organ could have played no active part in manipulating the food to be swallowed. On several occasions resting turtles were observed to move their lower jaw straight back a distance of 1-2 cm. Whether or not this movement was used in feeding was not determined. Ingle and Smith (1949) state that green turtles "appear to bolt their food without mastication," but the turtles at Marineland crushed their food either intentionally or in maneuvering it to the back of the mouth.

Locomotion. Aquatic locomotion fell into two main categories — swimming and crawling. In forward swimming, the propulsive stroke of the foreflippers was usually directed downward and backward at an angle of 10-15 degrees from the vertical. The leading edge was about 4-5 cm lower than the trailing edge. The propelling stroke also produced a slight upward movement of the turtle in the water. During the recovery stroke the leading edge was 2-4 cm above the trailing edge. Thus, although the downward (propulsive) stroke was much more powerful, a sculling force was created on the upward (recovery)

stroke, the effect of which was seen in a slight downward movement of the turtle in the water. Normally there were 10-30 complete strokes per minute.

The posterior flippers during forward swimming were held horizontally outward and backward, and were used only as elevators. During normal turning the posterior flippers were held nearly vertically and used as rudders. Often when turning, the vertically held flipper on the inside of the turn was moved rapidly forward. When maneuvering, the turtles used various transitory combinations of limb movements.

Crawling consisted mainly of the same series of limb movements that is found in the gait of such animals as newts or lizards, *i.e.*, the right front and left hind flippers were brought forward simultaneously. This type of crawling was usually used as long as the flippers were in contact with the bottom. Thus it was employed when an individual was starting to swim from a resting position or when a considerable distance was traveled over the bottom. Transitory scrambling movements, consisting of irregular use of the limbs, were common during feeding or when recovering from an upset caused by a water current or a porpoise.

Gray (1953, p. 22) states: "A good example of paddle locomotion is the turtle, whose limbs are flattened rather like the blade of a canoe paddle. When the paddle is moving backwards, the broad surface of the blade is held square to its line of motion, and thus exerts a powerful pressure against the water; at the end of the driving stroke, the blade is feathered and moves forward, thus exerting much less pressure against the water." Although the first few strokes of a rapidly accelerating sea turtle may approach this general description, Carr (p. 24) describes the usual movement much better when he states that "the highly modified fore flippers are raised and lowered like the wings of a bird in flight."

Scratching. On numerous occasions the turtles were observed to scratch themselves vigorously and thoroughly. An old anchor, a rock, another turtle, and a simulated shipwreck were frequently used for this activity. The longest observed period of continuous scratching was 20 minutes. Pope (1955, p. 67) comments that sea turtles may derive apparently pleasant sensations from a stimulus of the skin and shell.

Respiration. When a submerged turtle was resting, it surfaced for air every 10-56 minutes. If it was active, it surfaced every 30 seconds to

10 minutes. Surfacing for air at night usually occurred about every 35-45 minutes.

Two types of respiratory patterns were observed. The first type occurred after activity or submergence for a short time. Then the individual took only a single breath (the term "breath" is used here to include a single exhalation and subsequent inhalation) and continued its previous activity. The second type occurred if the turtle stayed down longer than 10-15 minutes. Then the individual took as many as five to eleven breaths at intervals which varied from 5 seconds to 3 minutes. During the day, between breaths of the second pattern, the turtles either swam at the surface or submerged. At night between breaths of the second pattern, the turtles either remained quiet at the surface or swam slowly, usually close to the surface. Variations rarely occurred. The intervals between breaths of the first pattern or between series of breaths of the second pattern varied with size and possibly with species, but the predominant factor was activity. An average of the intervals between breaths for adults would mean little because of the patterns, extremes, and activity involved.

Layne gave the following data for his loggerheads. When swimming actively, the minimum interval between breaths was 15 seconds, the average was 2.1 minutes, and the maximum was 24 minutes. When resting, the average interval between breaths was 12.7 minutes and the maximum was 25 minutes. The difference in breathing rates of the two groups of turtles can possibly be explained by a difference in size, since the individuals at Marineland were over twice as large as Layne's.

Ingle and Smith (1949) reported that loggerheads in captivity at Marine Studios "lie on the bottom in the winter months coming to the surface about every 3 hours to breathe." None of the turtles were observed to be this inactive during the course of this study.

Territoriality. Territoriality¹ was exhibited in swimming, resting, and sleeping; most of the turtles had one or several favored places for each activity. Degrees of territoriality varied with the individuals. Some of the turtles changed their territories at the end of relatively short periods (days), others at the end of long periods (a month or more). When the animals were removed to a different tank during the period of renovation, they were never observed to adopt a corresponding terri-

¹The term territoriality is used as defined by Allee, W. C., *et al.* (1949, p. 412). If a distinction is made between "home range" and "territoriality" (Odum, 1953, p. 161) then the writer feels that the term home range would better characterize the condition occurring at Marineland.

tory in the temporary tank, *i.e.*, if one swam along the northwest wall of the circular tank, it did not swim along the northwest wall of the temporary tank. However, at least four individuals which were removed from the rectangular tank reoccupied their favorite territories when replaced in this tank.

Layne states that his loggerheads exhibited "a certain amount of territoriality" when resting. He also mentions that one turtle would sometimes bite another that had usurped its territory—an observation that was confirmed in the present study. At least one instance was observed at Marineland, however, in which a resting turtle was chased from its favorite place by an usurper.

Resting. There were four basic resting positions. The first position may be termed the full juvenile because hatchlings almost invariably rest thusly. It consisted of the anterior flippers being positioned flat on the carapace, the posterior flippers being held close together behind. The second basic position was a semi-juvenile, *i.e.*, the anterior flippers were extended laterally, while the posterior flippers were held close together. The third was also a semi-juvenile, but the anterior flippers were positioned flat on the carapace and the posterior flippers were extended laterally. The fourth was a complete spread-eagle position, *i.e.*, all four flippers were extended laterally. Position four was seen most often; positions two and three were not uncommon. Variations of these positions occurred occasionally, *e.g.*, resting with one anterior flipper, or both, under the plastron.

During resting the eyes were kept open and the turtles seemed well aware of external stimuli, as indicated by their eyes following the movements of other turtles, fish, the observer, etc. Usually the head was thrust into a rock crevice or brought near a porthole, which to the turtles presumably resembled a darkened recess. Occasionally a resting turtle was well removed from rocks or portholes.

In the literature there is frequent mention of turtles resting and sleeping at the surface. It is possible that water depth may have an influence on this habit; the turtles at Marineland, in comparatively shallow water (depth 3.7-5.5 meters), were never observed to rest or sleep at the surface. Carr (p. 388) comments as follows: "In the open sea loggerheads often spend a great deal of time floating on the surface, presumably sleeping, but I never saw them do this in the sounds and estuaries, where they stay in the deeper parts of the channels and come up only for breath or for brief reconnaissance." Mellen (1925) reports

that Pacific green turtles (*Chelonia mydas agassizii* Bocourt) occasionally crawl out on the beaches to sun themselves, and Carr raises the question as to whether or not it happens in the Atlantic race. The tanks at Marineland were not constructed so as to permit the turtles to leave the water; consequently, observations could not be made on this particular phase of their behavior.

Sleeping. Sleeping began at sundown. The turtles did not go to sleep immediately upon coming to rest on the bottom; rather they dozed off slowly, taking about 5-10 minutes to reach a state judged to be sleep. A delay in getting back to sleep was also apparent after surfacing for air at night.

The green turtles slept all night; the loggerheads did most of their sleeping before 1:00 A. M., though they showed little activity in the pre-dawn hours. Activity of the turtles as a whole, beginning a few hours before sunrise, showed a steady increase, so that when the tank was light, the usual amount of diurnal activity was in evidence. Sleeping was observed only occasionally in the daytime. All species closed their eyes to sleep, with the exception of the ridleys, which were never seen with their eyes more than half closed.

The individual turtles at Marineland exhibited a marked variety of personalities, and individual traits were recorded. However, these individual differences were not considered of sufficient importance to be reported here.

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NAMES OF THE BLUE MARLIN AND BLACK MARLIN

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ABSTRACT

Examination of type material in the British Museum (Natural History) allowed identification of older names with currently accepted species. The Atlantic blue marlin is named *Makaira herschelii* (Gray), dating from 1838. The Pacific black marlin is named *Istiompax brevirostris* (Playfair), dating from 1866. Brief diagnoses and synonymies are given.

INTRODUCTION

Examination of type material in the British Museum (Natural History) has shown that the currently employed names for the blue marlin and the black marlin are ante-dated and should be changed. The synonymy and discussion which follow here are by no means complete, but are put forward at this time in the hope of helping to standardize the confused nomenclatural situation existing in this group at the present time. A more detailed treatment will be published later.

Makaira herschelii (Gray)—Atlantic blue marlin

Tetrapturus Herschelii Gray, 1838

Tetrapturus amplus Poey, 1860

Makaira perezi de Buen, 1950

The type specimen of *Tetrapturus herschelii* Gray, 1838 (BMNH 1953.2.3.2) from Table Bay, Cape of Good Hope, South Africa, is a stuffed skin, in rather poor condition. The skin of the body is completely separated from the head and tail, making accurate measurements impossible. The pectoral fins have become separated from the skin, permitting examination of the articular surface of the first ray. The ventral fins are broken, and another set accompanying the specimen is from a sailfish. Except for the posterior portion of the left cleithrum, the pectoral girdle is missing.

Counts and measurements (in millimeters) made on this specimen are as follows: Fork length, ca 3430 mm; standard length, ca 3200; depth of body, ca 550 mm (Since most of the stuffing has been removed from the specimen and the skin is partially collapsed, the measurement of body depth is undoubtedly too high. It is estimated that a depth of about 500 mm would be more realistic); height first dorsal, 411; height first anal, 377; length base first anal, 397; length pectoral, 550; snout tip to posterior end maxillary, 807; snout tip to

eye, ca 683; tip mandible to posterior end maxillary, 387; postorbital, ca 310; eye diameter, ca 66; elements first dorsal, 45; elements first anal, 14.

Diagnostic characters. D. 45; A. 14. Height of first dorsal approximately 75% of body depth (see comment above); height of first anal 91.8% of height of first dorsal. Articular surface of first pectoral ray large, more or less circular. Posterior portion (blade) of cleithrum nearly straight on its ventral edge, ventral corner rather sharply-rounded, posterior edge quite straight, dorsal corner broadly rounded.

These characteristics leave no doubt that the specimen is a blue marlin, but, except for the shape of the blade of the cleithrum, there is nothing to indicate whether it is an Atlantic form or an Indo-Pacific. Since Table Bay is within the occasional range of the Agulhas Current of the Indian ocean, this question is critical. Fortunately, it has recently been found (Morrow, 1957) that the cleithra of these two species provide a means of distinguishing the one from the other. Accordingly, the fragment of the cleithrum of *M. herschelii* has been projected against the same bone of three Atlantic and three Indo-Pacific specimens, all enlarged or reduced to the same size. The results are shown in Figures 1a and 1b. It is at once obvious that the cleithrum of *M. herschelii* fits very well on the outlines of the Atlantic specimens, but that it does not fit at all on the outlines of the Indo-Pacific individuals. Hence, despite the fact that the known centers of abundance of the

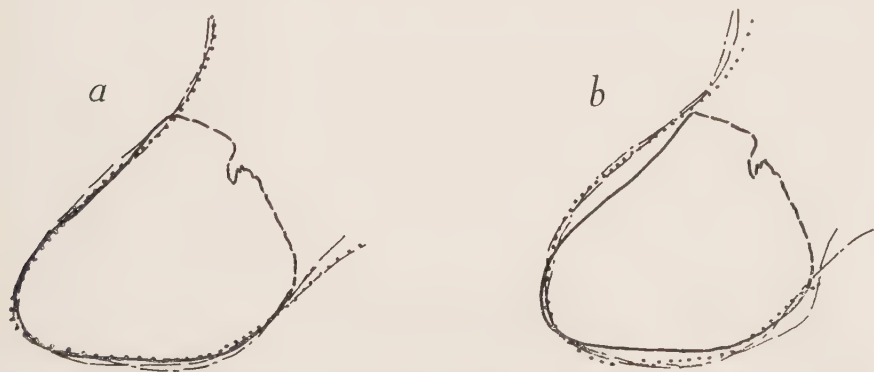


FIGURE 1. Posterior portion of the cleithrum of the type of *M. herschelii* projected against the cleithra of Atlantic (Figure a) and Indo-Pacific (Figure b) specimens. — type of *M. herschelii*. — — largest specimen of known origin. smallest specimen of known origin. — - — a specimen of intermediate size. The heavy dashed line indicates the broken edge of the bone fragment of *M. herschelii*.

Atlantic blue marlin are in the western north Atlantic, it is without hesitation that the name, *Makaira herschelii*, is assigned to this species.

Istiompax brevirostris (Playfair)—Black marlin, shirokajiki

Histiophorus brevirostris Playfair, 1866

Makaira marlina Jordan and Hill, 1926

Istiompax australis Whitley, 1931

Makaira nigricans tahitiensis Nichols and LaMonte, 1935

Marlina marlina Hirasaka and Nakamura, 1947

Istiompax dombraini Whitley, 1954

Makaira mazara non Jordan and Snyder, 1901 *sed* LaMonte, 1955

The type of this species is a stuffed specimen (BMNH 1866.8.18.1) from Zanzibar, of which there remains only the skull, left pectoral fin, complete pectoral girdle, tail, dorsal and anal fins, and some of the skin. There are 39 spines and rays in the dorsal fin, 11 in the anal. These counts indicate the black marlin, a conclusion which is definitely established by the characteristics of the pectoral articulation and the pectoral girdle. The girdle as a whole matches the descriptions given by Nakamura (1938) and Morrow (1957). The articulation for the first pectoral ray lies entirely on the lateral aspect of the scapula and is rather broader dorsally than at its ventral end. The end of the first pectoral ray is more or less rectangular, with the articular surface confined to the dorsal third of the end of the ray. The characteristic foramina are present around the articular surfaces of both scapula and first ray. These characteristics are adequate to establish identification as a black marlin.

Smith (1956), on the basis of a reconstruction from measurements given by Playfair in the original description, has suggested that *I. brevirostris* might be the black marlin, although the measurements alone will scarcely serve to separate this species from *M. mazara*. This same thought has also been put forward, though more tenuously, by other authors from time to time. The identification is now confirmed, and since *brevirostris* has priority by 60 years over *marlina*, the latter name is relegated to the synonymy.

These observations were made possible, while en route home at the conclusion of the Yale Seychelles Expedition, through the generous support of Mr. Alfred C. Glassell Jr. and Col. John K. Howard. I am also indebted to Dr. E. Trewavas and Mr. G. Palmer of the British Museum (Natural History) for access to the type material.

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STUDIES ON FISHES OF THE FAMILY OPHIDIIDAE.—I. A NEW SPECIES OF *LEPOPHIDIUM* FROM THE CARIBBEAN SEA¹

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ABSTRACT

A new species of *Lepophidium* (Pisces: Ophidiidae) is described from the western Caribbean. The holotype of *Lepophidium jeannae* Fowler is redescribed and additional features discussed. Other species of *Lepophidium* are briefly discussed and the first gill arch of various Atlantic species is illustrated.

INTRODUCTION AND ACKNOWLEDGMENTS

Among the collection of cusk eels recently sent to the writer for study is a distinctive new species of the genus *Lepophidium*. The species is described below.

Harvey R. Bullis, Jr., of the United States Fish and Wildlife Service, has kindly provided specimens obtained during trawling operations of the research vessel OREGON. Loren P. Woods loaned specimens from the collections of the Chicago Natural History Museum. Comparative material of other species was generously loaned by James E. Böhlke of the Academy of Natural Sciences of Philadelphia, Leonard P. Schultz, Ernest A. Lachner and Robert H. Kanazawa of the United States National Museum, Giles W. Mead of the United States Fish and Wildlife Service, John C. Briggs and Daniel M. Cohen of the University of Florida, Royal D. Suttkus of Tulane University and Vladimir Walters of the American Museum of Natural History. Walter R. Courtenay, Jr. provided the photographs and aided in many ways. This study has been supported in part by a grant-in-aid from the National Science Foundation (NSF-G-3881) and constitutes a technical report to that organization.

Lepophidium staurophor, new species

Table 1, Figs. 1-2

Diagnosis. A *Lepophidium* with four or five black bands on the body, the last two complete. Dorsal fin with five or six black areas, the anterior two merging with the anterior bands to form cross-like marks on the dorsum. Caudal fin sharply bicolored, black below and white above. Dorsal and anal rays numerous, 140-147 and 122-127 re-

¹Contribution No. 218 from The Marine Laboratory, University of Miami.

spectively, caudal rays, 9, pectoral rays, 22 or 23, pyloric caeca, 3, gill rakers, 12-15.

Description. *L. staurophor* shares with other species of *Lepophidium* the following morphological features: 1) a prominent rostral spine, 2) a strong, hidden spine at the upper posterior margin of the opercle, 3) an elongate body that tapers to a pointed caudal region, 4) small scales on the body, somewhat overlapping and in regular rows, 5) a large and relatively thin-walled gas bladder which lacks a posterior foramen and projection, 6) head and cheeks fully scaled behind the interorbital region.

Fin-ray counts and morphometric data are presented in Table 1. There are 7 branchiostegal rays per side and 9 caudal rays in each specimen; no individual or specific variation in these features has been noted by the writer for any ophidiid. Gill rakers number 4 + 8 in three specimens (including the holotype) and 4 + 11 in one or a

TABLE 1

Meristic and morphometric data for the types of *Lepophidium staurophor*. Numbers in parantheses indicate percentage of standard or (*) head length. All measurements are in millimeters.

Character	holotype	paratypes		UMML 2349
	CNHM 64383	CNHM 64383(1)	(2)	
Standard length	236	260	232	224
Head length	45 (19)	51 (20)	44 (19)	49 (22)
Predorsal distance	53 (22)	61 (24)	53 (23)	51 (23)
Preanal (fin) distance	87 (37)	105 (40)	84 (36)	83 (38)
Tip snout to occiput	30 (13)	33 (13)	28 (12)	29 (13)
Depth of body:				
1) at dorsal-fin origin	34 (14)	29 (11)	31 (13)	33 (15)
2) at anal-fin origin	24 (10)	28 (10)	22 (9)	23 (10)
3) at occiput	28 (12)	—	27 (12)	—
Pectoral-fin length*	19 (42)	22 (43)	20 (46)	20 (41)
Caudal-fin length*	8.6 (19)	8.4 (16)	8.3 (19)	7.9 (16)
Pelvic-ray length:				
1) outer*	26 (57)	36 (70)	27 (61)	25 (50)
2) inner*	20 (45)	27 (53)	26 (60)	18 (38)
Snout length*	9.3 (21)	10.0 (20)	8.5 (19)	9.3 (18)
Postorbital length*	26 (58)	28 (55)	25 (56)	28 (57)
Maxillary length*	22 (49)	25 (49)	22 (49)	25 (50)
Diameter bony orbit*	12 (26)	13 (27)	11 (25)	12 (25)
Bony interorbital*	7.5 (11)	6.6 (13)	6.3 (11)	6.5 (13)
Dorsal rays	144	147	145	140
Anal rays	122	127	124	124
Pectoral rays	23-23	23-23	22-23	23-22
Caudal rays	9	9	9	9

variation in total count from 12-15. Specific differences in gill rakers apart from numbers require more detailed description and this seems best accomplished by an illustration (Fig. 1a). In *L. staurophor*, the gill rakers form a graded series with the longest, near the angle of the arch, equal to two-thirds the pupil diameter. Three pyloric caeca, two ventrally and one dorsally, are present in all specimens. Vertebral counts range from 80-82. Precaudal vertebrae number 15 in all specimens; caudal vertebrae number 65, 66 and 67 in the three paratypes, 66 in the holotype.

The scales are small, cycloid and difficult to enumerate. They are slightly imbricate and arranged in regular rows. Approximately 230 rows cross the body behind the attachment of the gill membrane. Ten scale rows are present above the lateral line at the dorsal-fin origin and about 37 rows are below the lateral line above the anal-fin origin. The dorsal surface of the head from the interorbital region forward, the snout, maxillary, suborbital region, the branchiostegal and opercular membranes and the gular region are naked.

Villiform teeth are present on the premaxillary, dentary, vomer, palatines and upper and lower pharyngeal bones. The outer row of premaxillary and dentary teeth, especially anteriorly, are somewhat enlarged. The shape and relative size of the palatine and vomerine patches are shown in Figure 1g.

Coloration is diagnostic for the species. The background coloration is tan except for one specimen (UMML 2349) which has a slightly reddish cast, perhaps a reflection of preservation. Melanophores dot the surface of the maxillary, and give a dusky appearance to lower portions of the snout, cheek and opercular region. On the body the melanophores are larger and more scattered ventrally so that the lower sides and ventrum are less uniformly colored and more smudged than the upper sides and dorsum. Four (the holotype and one paratype) or five (two paratypes) prominent black bands cross the dorsum and extend variously onto the side. The first passes through the base of the anterior 3 to 7 dorsal rays and forms a rectangular band on the upper side. It extends below the lateral line to a distance about equal to the distance from the lateral line to the dorsal-fin origin. In one specimen the first band tapers to a point about 13 scale rows below the lateral line. It is sharply defined and set apart from the general ground coloration by a narrow pale region. Band 2 crosses the dorsum a little caudad of the anal-fin origin. It fades on the lower side well above the venter. Compared to the anterior band, the second is nearly

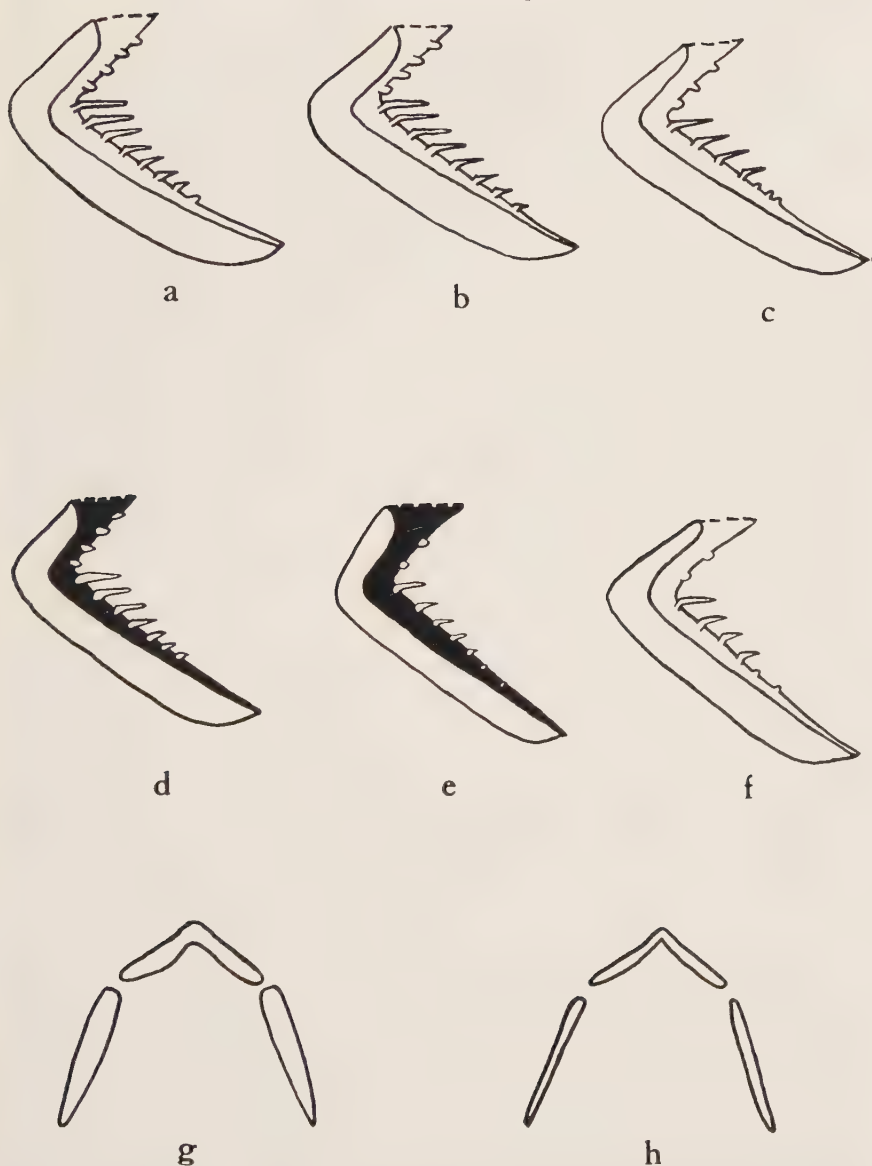


FIGURE 1. Outline of first gill arches of Atlantic species of *Lepophidium* and of the palatine and vomerine tooth patches of *L. staurophor* and *L. jeannae*. Gill filaments and teeth are omitted for clarity. Figures are of individuals but variation in numbers of gill rakers is limited. The scale is varied. a and g, CNHM 64383, holotype of *L. staurophor*. b, UMML 1163, *L. marmoratum*. c, UMML 800, *L. profundorum*. d, UMML 2323, *L. brevibarbe*. e, UMML 594, *L. cervinum*. f and h, ANSP 69724, holotype of *L. jeannae*.

twice as broad and less well defined at its border. It too is set off by a narrow pale area. The third band may or may not encircle the body; the fourth band does so in the type series but may be ill-defined ventrally. Band 3 is slightly nearer the caudal base than the anus and band 4 is one-third of the distance from band 3 to the caudal base. In one paratype, band 3 is asymmetrical. On the left side only the posterior portion is developed which creates a large gap between bands 2 and 3. On the right side the band is broad and the first four bands are evenly spaced. Band 5, when present, is midway between band 4 and the caudal base. It encircles the body. In the two paratypes that lack this band, it is represented instead by an elongate dark smudge ventrally. The pale areas that so sharply set off the first two bands are less obvious around the posterior bands. A small dark saddle, interrupted at the mid-dorsal line by the pale fin base, may be present midway between any of the first 4 bands but this feature shows considerable individual variation.

There are five or six black areas in the dorsal fin. The first two coincide with the anterior two body bands and form two crosses on the mid-dorsal line. The dorsal-fin markings become closer together caudally and the remaining three or four may or may not coincide with other body bands. The anal fin is largely unmarked. At the caudal end, a dark basal area merges with the black on the lower portion of the caudal fin. A second dark basal area marks the anal fin under band 5 (when present). In one specimen the two dark areas in the anal-fin membrane merge to form a dark basal streak, somewhat bimodal in form. The caudal fin is sharply bicolored, black below and white above. The pectoral and pelvic fins are unmarked.

The palate is dark but shows light-colored longitudinal streaks. Only the anterior part of the gill chamber is dark.

Recent workers (Harry, 1951:32, Briggs and Caldwell, 1955:287-288, Robins, 1957:269) have shown important features in the structure of the gas bladder of other ophidiid species. In *L. staurophor* and apparently in most if not all species of *Lepophidium* the gas bladder is large and rather thin walled. There is no opening or projection on the caudal portion. A large circular opening is present on the anterior ventral surface and is covered by a delicate membrane. In the holotype the gas bladder is 30 mm long and the diameter of the foramen equals 5 mm.

Distribution. *L. staurophor* is known from the Caribbean waters off southern Nicaragua northward to the region between Honduras and



FIGURE 2. Lateral view of *Lepophthalmus stansboroughi*. a, UMNIL 2349, female paratype, standard length 224 mm, OREGON station 1904. b, CNHM 64383, male holotype, standard length 236 mm, OREGON station 1878.

Jamaica. Complete locality data are given below. The known vertical distribution is from 125 to 145 fathoms.

Material examined. Holotype (male): CNHM 64383 (1,236) 16°39' N, 81°43' W, 125 fathoms, August 22, 1957, M/V OREGON station 1878. Paratypes (all females): CNHM 64384 (2,232-260) 15°15' N, 81°19' W, 145 fathoms, August 25, 1957, M/V OREGON station 1894. UMML 2349 (1, 224) 11°34' N, 83°07' W, 125 fathoms, September 10, 1957, M/V OREGON station 1904. All were collected with a 40-foot flat trawl.

Name. The specific name "*staurophor*" is derived from the Greek words for "cross" and "to bear," and refers to the cross-like markings on the dorsum.

Relationships. Twelve species of *Lepophidium* are known exclusive of the present form. All are from American waters and their distribution is essentially tropical. Six, *L. cervinum* (Goode and Bean) *L. profundorum* (Gill), *L. marmoratum* (Goode and Bean), *L. brevibarbe* (Cuvier), *L. fluminense* Ribeiro and *L. jeannae* Fowler are from Gulf and Caribbean waters except for *cervinum* which ranges northward along the eastern seaboard to George's Bank and *fluminense*, a nominal form known only from Ilha Rasa, Brazil. Six, *L. prorates* (Jordan and Bollman), *L. emmelas* (Gilbert), *L. pardale* (Gilbert), *L. microlepis* (Gilbert), *L. stigmatistium* (Gilbert) and *L. negropinna* Hildebrand and Barton are from the Pacific Coast from Peru to southern California. Of the Atlantic forms, *profundorum* and *brevibarbe* are of uniform coloration except for a black margin to portions of the vertical fins. *L. cervinum* has a row of large pale spots. Only *marmoratum* and *jeannae* are extensively marked with black. The illustration of *marmoratum* by Goode and Bean (1895, pl. 87, fig. 308) compares favorably with fresh material of *marmoratum* at hand, and is entirely unlike *staurophor*. For comparison the first gill arch of each of the known Atlantic species is diagrammed in Figure 1. Although these drawings are of individuals there is little individual variation in the numbers of rakers and none in the degree of development. Note that the gill bar is black in *cervinum* and *brevibarbe*, pale in the others. Many other differences exist but further comment on them is beyond the scope of this paper. None of the Pacific forms closely resembles *staurophor* (see Hildebrand and Barton, 1949:28-31).

The holotype of *L. jeannae* (ANSP 69724; 41.0 mm in standard length) is a juvenile fish in poor condition. Thanks to James E. Böhlke

the writer was able to examine the type on several occasions, recently in considerable detail. Of the prominent pattern described by Fowler (1941: 103, fig. 17) only a faint suggestion of the posterior two dark markings on the body remained when the specimen was first examined; they have since become obscured. There is no suggestion of any black markings in the anterior portions of the dorsal fin as in *staur-ophor*, and it is unlikely that such intense markings would fade completely. Several features of Fowler's description perplexed the writer. First, the maxillary is shown to extend beyond the posterior margin of the orbit a feature not known to the writer in any other species of *Lepophidium*. Reexamination shows that the maxillary ends slightly in advance of the posterior margin of the eye and well in front of the posterior rim of the bony orbit. The dorsal- and anal-ray counts are recorded as "88?" and "70?". They are vastly fewer than similar counts in any other species of *Lepophidium* or, for that matter, any ophidiid known to the writer other than the remarkable and primitive *Umalius philippinus* Herre and Herald; (USNM 112107, holotype of *U. philippinus*, was reexamined: dorsal rays, 86, anal rays, 64). Although the type is small and in poor condition the rays may be accurately counted with the aid of high magnification. The dorsal rays, in fact, number 135 and the anal rays, 114. There are nine caudal rays. The pectoral rays are more difficult to enumerate but there appear to be 22 in the one fin whose basal portion is still reasonably intact. There are surely more than 17 pectoral rays. Two important additional features may be noted. There are 3 pyloric caeca, 2 ventrally and 1 dorsally. The gill rakers consist of two rudiments on the dorsal arm, 4 developed rakers on the lower arm and 2 or 3 rudiments (the two sides differ) on the lower arm for a total count of 8 or 9 (fig. 1f). This pattern of gill raker development is like that of *profundorum* but unlike that of *staurophor*. Palatine and vomerine tooth patches of *jeannae*, (fig. 1h) are essentially like those of *staurophor*. In summary, *jeannae* differs from *staurophor* in dorsal- and anal-ray counts and in the gill rakers. *L. jeannae* is sufficiently unlike any other species of *Lepophidium* in these features to merit specific ranking.

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THE CEPHALOPODS COLLECTED BY THE R/V ATLANTIS DURING THE WEST INDIAN CRUISE OF 1954.^{1,2}

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ABSTRACT

The present report is based upon a collection of cephalopods made by the Woods Hole Oceanographic Institution's research vessel ATLANTIS in the West Indies in 1954. The collection consists of 83 specimens representing 17 genera and 18 species of which one genus, *Selenoteuthis*, and two species, *Selenoteuthis scintillans* and *Abralia grimpei*, are new to science.

INTRODUCTION

This study is based upon a small collection of cephalopods collected by the Woods Hole Oceanographic Institution's research vessel ATLANTIS during a cruise to the West Indies in 1954. The material, consisting of 83 specimens, is very rich and contains 17 genera and 18 species of which one genus and two species are new to science. Of particular interest in the collection is the new species of lycoteuthid squid which, by the arrangement and size of its light organs, must rank among the most brilliant of all of our luminous bathypelagic species. Also worthy of note is the new species of *Abralia*. For many years this genus was thought to be primarily Indo-Pacific in distribution and was represented in the Atlantic by a single species. Within only a few years the number of species of this genus has been raised to three and the whole Atlantic cephalopod fauna is being shown to be equal in importance to that of the other large oceanic areas.

The author is indebted to Dr. Richard H. Backus of the Woods Hole Oceanographic Institution for the opportunity to study this collection made by him during the 1954 cruise, for reading the manuscript, and for observations concerning the gear used. In particular he wishes to thank the Woods Hole Oceanographic Institution and Dr. Alfred C. Redfield, formerly Associate Director, for the financial support in the form of a Fellowship which enabled him to carry out the study both at Miami and the Museum of Comparative Zoology at Harvard College. The illustrations of *Abralia* are by the author's wife, Nancy A. Voss; the others were drawn by the author. All abbreviations and measurements are as defined by Voss (1956).

¹Contribution No. 994 from the Woods Hole Oceanographic Institution.

²Contribution No. 213 from The Marine Laboratory, University of Miami.

The specimens were captured by means of an Isaacs-Kidd Midwater Trawl (IKMT). Since this is not a closing net, the specimens might have been taken anywhere between the surface and the depths indicated. As the net fishes at the depth indicated for a period considerably longer than the time needed for lowering or hauling in, statistically the chances are greater that they came from the depth recorded. The depth in meters was obtained by a telemetering device and represents the actual depth fished instead of meters of wire out.

Order SEPIOIDEA

Family SPIRULIDAE Orbigny

Spirula spirula (Linnaeus, 1758)

Nautilus spirula Linnaeus, 1758, p. 710.

Material. 2 ♀ ♀, ML 32.0 and 42.0 mm, Stn. RHB 582, in 504 meters, March 2, 1954. UMML 31.175.

Both specimens were taken alive and are in an excellent state of preservation. The larger one is intact, with the skin covering the shell both dorsally and ventrally; the smaller one has the skin ruptured and several chambers of the shell are crushed.

Bruun (1943) has summarized the present information on the biology and distribution of this interesting species. In 1955 he also published a more detailed account of the vertical distribution and has suggested the term "mesopelagic" for the level at which they are found. According to his table (1955, p. 67) the present specimens came from a greater depth than any yet recorded from the West Indies.

Order TEUTHOIDEA

SUBORDER OEGOPSIDA

Family LYCOTEUTHIDAE Pfeffer

Selenoteuthis, new genus

Lycoteuthids with short, wide fins; a large round light organ at the end of the mantle and a small round light organ at the tip of the 2nd and 3rd arms; 10 light organs within the mantle cavity and two on each of the tentacular stalks; buccal membrane 8 lobed with 8 supports.

Type species: Selenoteuthis scintillans, n. sp.

Selenoteuthis scintillans, n. sp.

Figure 1 a-e

Holotype. A male, in alcohol, ML 32.5 mm, from Stn. RHB 587, 26°22'N, 76°10'W, IKMT net, from 46 meters; 2003 - 2111 hours,

March 21, 1954. To be deposited in the Museum of Comparative Zoology.

Description. I have referred this specimen to the lycoteuthids with some reservation. It is a remarkable species and a living individual must be spectacular.

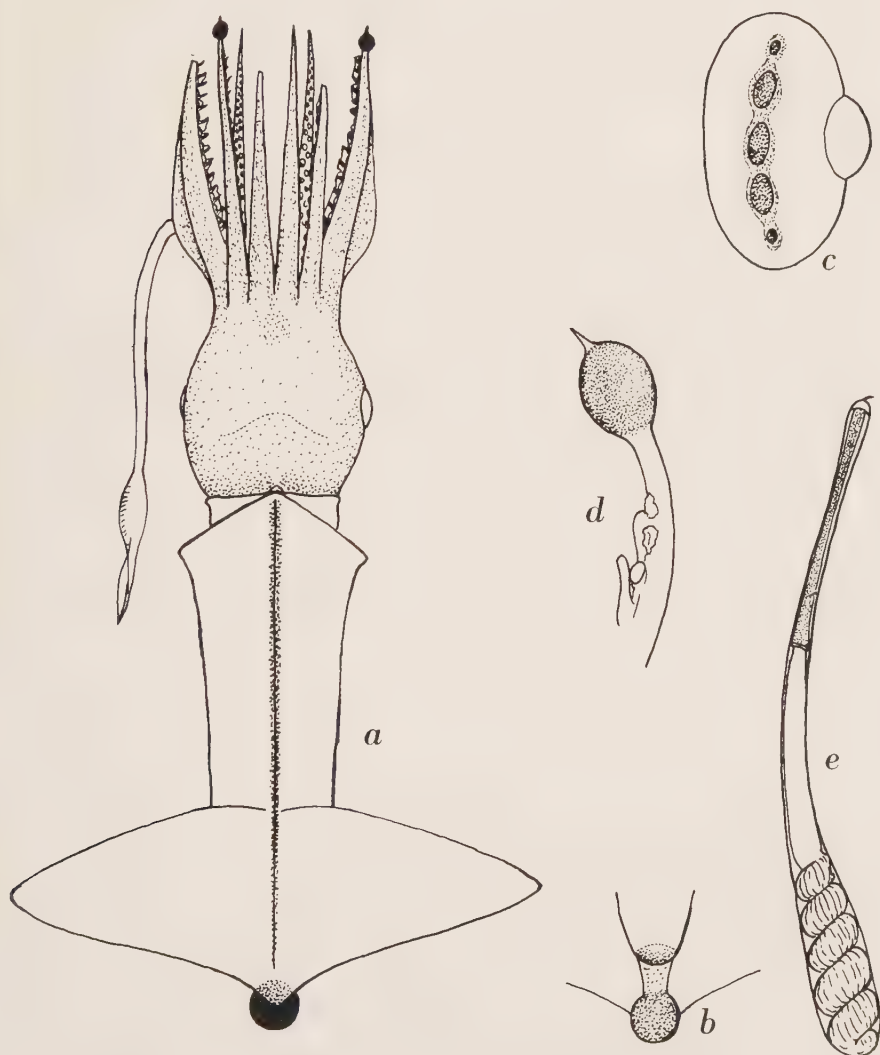


FIGURE 1. *Selenoteuthis scintillans* n. sp. a. Dorsal view, b. Terminal light organ of mantle, c. Left eyeball, ventral view to show light organs, d. Apical light organ of left dorso-lateral arm, e. Spermatophore.

The *mantle* is rather long and slender (Fig. 1 a), the anterodorsal margin sharply produced. There is no excavation in the ventral mantle margin beneath the funnel. The posterior end is bluntly pointed, but the mantle is somewhat curved downward due to fixation and a break in the dorsal surface of the mantle, so that the true contour is difficult to see. At the end of the mantle and entirely projecting beyond the fins is a large round light organ (Fig. 1 b). This does not occur in any other lycoteuthid.

The *fins* are short and very broad, terminal except for the black photophore projecting beyond them. The anterior margins are convex, the posterior margins concave. The lateral corners are sharply pointed.

The *funnel* is large and stout, free for only the distal $\frac{1}{4}$ of its length and provided with a small but strong dorsal support. The funnel organ is uncomplicated and consists of an inverted V shaped dorsal member with short, shouldered limbs, and fat, thick ventral pads. The funnel valve is large, sub-terminal and slightly bilobed. The mantle locking apparatus consists of a simple, slightly curved funnel groove on each side and a corresponding ridge on either side of the mantle. The nuchal cartilage is elongate, swollen and rounded posteriorly and widely pointed anteriorly.

The *gladius* may be seen through the dorsal mantle wall but was not dissected out.

The *head* is short and broad, nearly as wide as the mantle, with large eyes. The eyes are equipped with five light organs around their periphery ventrally. At each end there is a very small round organ, separated by three large round organs (Fig. 1 c). All appeared to have been bright red in the living animal and in the preserved specimen they had a distinct reddish hue. The light organs on both eyes were somewhat damaged. The beaks were not dissected out but appeared normal. The buccal membrane is 8 lobed with 8 prominent supports. The entire membrane is reddish purple and is strongly papillose on the outer surface.

The *arms* are in the order $2 = 3.1 = 4$. No keels could be seen, but all of the arm tips are very attenuate. In addition, there is a small brownish black light organ just below the tip on the 3rd arm of the right side and the 2nd arm of the left side (Fig. 1 d). The tips of the corresponding arms of these pairs were missing. The suckers of the arms are biserially arranged, bordered dorsally by a low indistinct protective membrane and ventrally by a very broad membrane with stout supports. The supports, however, are torn free from the mem-

brane and present a fringed appearance. The suckers are equipped with about 7-9 long teeth on the distal margin of the horny ring. The proximal edge of the ring is entire. There is no apparent hectocotylization of any of the arms.

Only the left *tentacle* is present. It is long and stout and bears a short club which is broad basally but attenuate for the distal $2/3$. The suckers are in four rows upon the hand part with the entire margin finely toothed. The carpal cluster is compact and consists of five suckers and about three discernible buttons. A protective membrane with prominent supports is located ventrally and a swimming membrane occupies about $1/3$ of the distal border on the dorsal side. Two large light organs of a silvery appearance are embedded on the aboral surface of the tentacular stalks, one basally, the other near the carpal section.

Internally there are 10 *light organs*. Two elongate, oval light organs lie within the funnel chamber, one on each side of the rectum. In the midsection of the mantle cavity are five light organs: a small longitudinally oval central organ, a large transversely oval light organ on each side, and a small round light organ attached to the base of each gill. In the posterior part of the mantle cavity there appear to be three photophores arranged in a transverse row, but these organs are badly damaged and their exact shape and number cannot be ascertained.

The spermatophores are short and stout and there are only a few turns of the sperm reservoir. The structure of the spermatophores is different from any yet described and is illustrated in Figure 1 e.

TABLE 1
MEASUREMENTS (IN MM) OF THE HOLOTYPE OF *Selenoteuthis scintillans* n. sp.

Sex	♂	Arms, I	12.0
ML	32.5	II	12.9
MW	12.0	III	12.9
HW		IV	12.0
HL	11.5	TL	27.5
FL	11.0	CL	6.8
FW	30.0	Diam. terminal light organ	3.0

The generic name *Selenoteuthis* or moon squid is derived from the Greek SELENE—moon and TEUTHIS—a squid, in reference to the large terminal light organ, and is in the feminine gender. The specific name *scintillans* is the present participle of the Latin *scintillo*, to glitter, sparkle or shine, here used as an adjective, sparkling.

Discussion. *Selenoteuthis scintillans* is the sixth species to be included

in the family Lycoteuthidae, and all six belong to monotypic genera. In general, in modern systematics, such generic splitting is frowned upon, but in the present situation no other recourse is at hand. With the exception of *Lycoteuthis diadema* (Chun, 1900) all of the other genera and species are known from unique specimens only. Lycoteuthids are rarely obtained, living apparently in the bathypelagic habitat, and little is known of their life history. Also, as most of the species are known only from females, the morphology of the males and differences in the genitalia are unknown.

Lycoteuthis diadema (Chun, 1900)

Enoploteuthis diadema Chun, 1900, p. 532.

Lycoteuthis diadema, Pfeffer, 1908, p. 294; 1912, p. 114; Voss, 1956, p. 118.

Asthenoteuthion planctonicum Pfeffer, 1912, p. 172, Pl. 15, figs. 8-14.

Material. 2 juveniles, ML 8.3 and 7.2 mm, from Stn. RHB 553, in 57 meters, Feb. 7, 1954. UMML 31.194.

1 juvenile, ML 8.7 mm, from Stn. RHB 574, in 46 meters, Feb. 25, 1954. UMML 31.194.

These three specimens seem definitely referable to this species on the basis of the shape of the fins, the light organs on the ventral surface of the eyeball, and the arrangement and number of the light organs within the mantle cavity.

In 1912 Pfeffer described a new genus and species, *Asthenoteuthion planctonicum*, based upon three larval specimens obtained by the German Plankton-Expedition. The mantle lengths were 4.5, 3.5 and 2.0 mm respectively. Due to the shape of the gladius in the largest of these, he considered them to belong to the family Enoploteuthidae and suggested relationship to the larvae of *Abraliopsis*, *Abralia*, etc. because of the shape and position of the fins. Finally he remarks, "Man könnte auf Grunde der Fünzfzahl der Leuchtorgane des Bulbus vielleicht an eine Verwandtschaft mit *Lycoteuthis* denken; aber der Gladius von *Asthenoteuthion* ist ein echter Enoploteuthiden-Gladius."

In the present specimens the gladius of the 8.3 mm specimen was dissected out and found to lie midway between the enoploteuthid like gladius described by Pfeffer and the true lycoteuthid gladius. Evidently Pfeffer's younger specimen was not far enough advanced in development to show its true affinities.

The most notable character of these larvae or juveniles, as well as in *Asthenoteuthion*, is the presence of five light organs on the ventral surface of the bulbus. The five organs are large, crowded and round, but as in *Lycoteuthis* the middle or 3rd organ is distinctly different

in color from the others. It is reddish in contrast to the clear opaque appearance of the other four and in the largest specimen available, 8.7 mm, a purplish sheen is distinctly visible. This coincides exactly with the organs in *Lycoteuthis*.

The mantle cavity of each specimen was opened and the visceral mass searched for the presence of the light organs peculiar to the lycoteuthids. In the 7.2 mm specimen, there were two light organs in the funnel, one on each side of the rectum, a small light organ at the base of the gills, and two light organs lying between the gills in a line across the visceral mass. In the 8.7 mm specimen there was a minute light organ lying between the median pair between the gills. These light organs correspond to those found in *Lycoteuthis* with the exception of the posterior three photophores which were completely missing in the present specimens, nor was there any evidence of the photophores in the tentacular stalks. Evidently these missing organs develop at a later stage.

The fins are small but have already attained their typical wide, pointed, lycoteuthid appearance.

Family ENOPLOTEUTHIDAE Pfeffer

Abralia grimpei, n. sp.

Holotype. ♀, preserved in alcohol, ML 27.0 mm, from Stn. RHB 551, 26°25'N, 79°45'W, IKMT net, from 57 meters, Feb. 6, 1954. To be deposited in the Museum of Comparative Zoology.

Diagnosis. Two rows of suckers on tips of arms; fins half the length of the mantle or less; two hooks on tentacular clubs; six to seven light organs on ventral periphery of eyeball; about nine rows of photophores on ventral surface of head.

Description. A single female of an *Abralia* was found in the collections. A number of characters distinguish it from the other members of the genus found in the Atlantic and Indo-Pacific areas and warrant its description here as a new species.

The *mantle* is long and cylindrical (Figs. 2 a, b), slightly produced in the midline dorsally and emarginated beneath the funnel. The posterior end is bluntly pointed.

The *fins* are of moderate length, united posteriorly, and with free anterior lobes. The anterior margin is strongly convex, the posterior margin concave. The mantle locking apparatus is slightly curved and strong.

The *funnel* is strongly developed (Fig. 2 c). The funnel organ (Fig. 2 d) is composed of a dorsal member shaped like an inverted

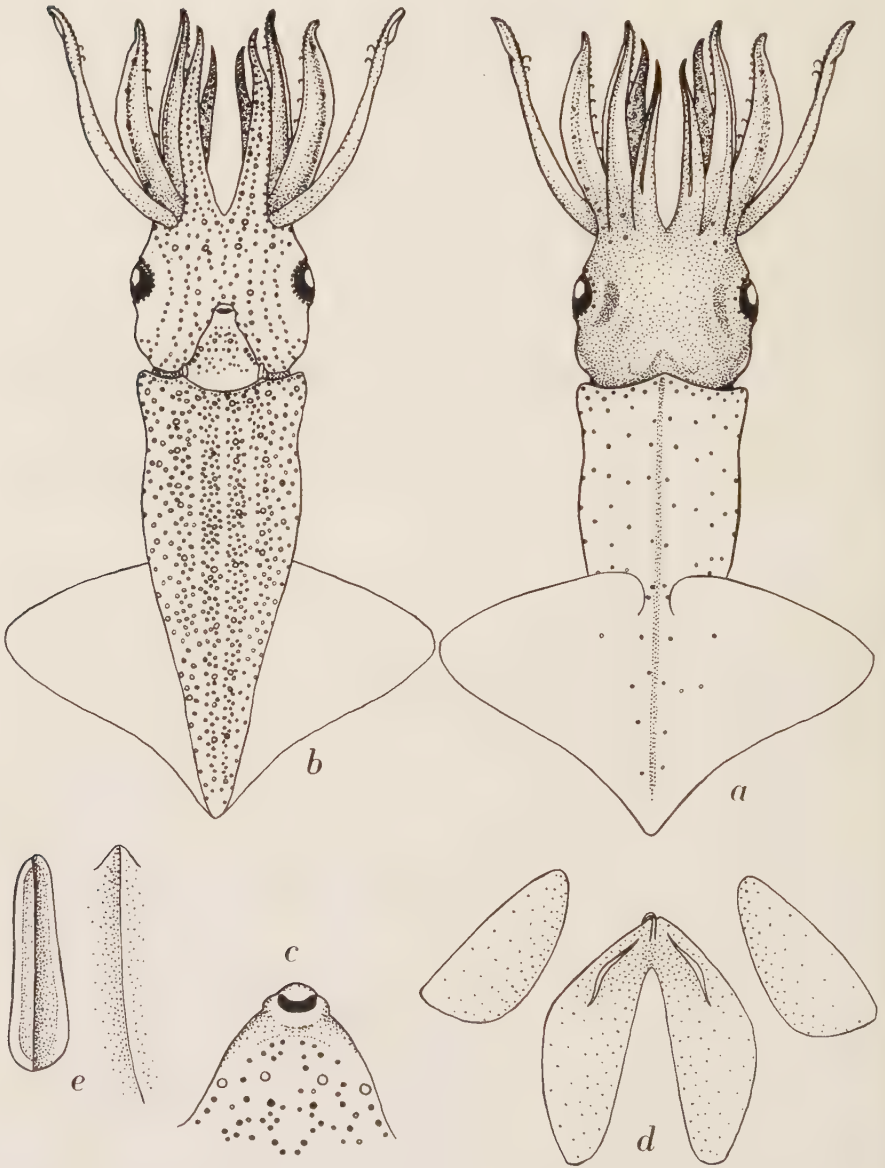


FIGURE 2. *Abralia grimpei* n. sp. a. Dorsal view, b. ventral view, c. Funnel, d. Funnel organ, e. Locking apparatus.

V with angled shoulders and two ventral pads which are large and slightly angled. The locking apparatus is shown in Figure 2 e.

The *arms* are in the order $4.1.2 = 3$. All of the arms, with the exception of those of the fourth pair, are keeled at least distally. The third pair is equipped with a strong swimming membrane. All of the arms (Fig. 3 a) bear about 13 hooks on the proximal $2/3$ of the arms (12 in IV) after which there are about 10-12 small suckers followed distally by a few minute suckers in two rows. The hooks (Fig. 3 b) and suckers are bordered by low protective membranes, the ventral one of III being somewhat larger than the others. The sucker rings are toothed on their outer margins but are entire on the inner margin (Fig. 3 c).

The *tentacles* are short and stout, the stalks oval in cross section and grooved orally. The clubs (Fig. 3 d) are moderately expanded and on the hand part are equipped with two rows of suckers with finely toothed margins (Fig. 3 e) and two large hooks (Fig. 3 f) on the ventral row. Distally the club bears four rows of small suckers. The carpal cluster consists of a block of five small, smooth ringed suckers and

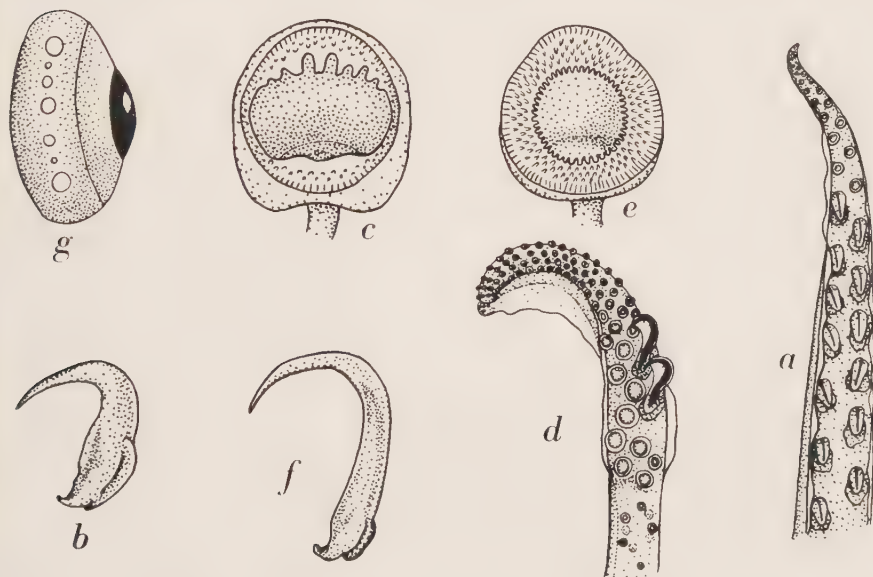


FIGURE 3. *Abralia grimpei* n. sp. a. Right dorso-lateral arm, b. Hook from fifth pair of dorso-lateral arm, c. Sucker from second pair of right dorso-lateral arm, d. Left tentacular club, e. Sucker from left tentacular club, inner row, third pair, f. Distal hook from left tentacular club, g. Left eyeball, ventral view.

about four low pads. Ventrally there is a semicircular protective membrane originating near the carpus and ending at the base of the distal hook. Beyond this is a low protective membrane which extends to the tip of the club. Aborally there is a strong keel on the distal half. Dorsally there is a low protective membrane originating at the carpus and extending over about half of the club.

As in all *Abralia* the specimen is liberally supplied with light organs. These are of the typical three types on the ventral surface of the head, funnel and mantle. There are large clear-centered organs, medium size dark ones and small dark organs with minute clear centers. They are arranged as follows.

On the ventral surface of the mantle and extending over the lower part of the sides are numerous light organs separated in the ventral midline and laterally by distinct bands of clear skin. This apparent orderly distribution may well be due to the action of the preservative. There are also scattered photophores on the dorsal side of the mantle. The ventral surface of the funnel (Fig. 2 c) bears about 56 light organs, 28 on each side, besides a patch of about 16 on each side of the funnel on the dorsal surface, squeezed in against the posterior surface of the head.

The ventral surface of the head bears about nine indistinct rows of photophores which unite anteriorly to form three distinct rows of light organs on the ventral arms occupying about 4/5 of the length of the arms. The dorsal row terminates here but the other two rows continue to just short of the tip. Only the median row continues to the extremity of the arm. There are about five small light organs on the ventro-lateral arms, distributed along the base of the swimming membrane. In addition, there are two light organs on the head at the base of the dorso-lateral arms and a single photophore a few millimeters from the base of these arms. Each eye has a distinct and orderly row of small light organs bordering the eyelids.

TABLE 2

MEASUREMENTS (IN MM) OF THE HOLOTYPE OF *Abralia grimpei* n. sp.

Sex	♀	Arms I	12.0
ML	34.0	II	11.5
MW	11.4	III	11.5
HW	12.4	IV	12.5
HL	11.0	Hooks I	13
FL	18.6	II	13
FW	28.0	III	13
TL	16.0	IV	12
CL	6.0		

The eyeballs bear light organs on the lower half of their periphery, arranged in a single row. The photophores are six in number on the right eyeball, consisting of a posterior and anterior roundish organ with three slightly smaller and less well-defined light organs between them and a minute light organ between the anteriormost one and its fellow. In addition to these, on the left eyeball (Fig. 3 g) a minute organ lies between the posteriormost light organ and its adjacent fellow, making seven photophores in all.

The beaks and radula were not examined.

Discussion. With the description of this species, the number of species of *Abralia* in the Atlantic is raised to three, each of which is easily distinguished from the others. These are compared below and a key is given to the Atlantic species. The species of the genus *Abralia* of the Pacific and Indian Oceans are presently being revised and will be published upon shortly.

The first Atlantic species, *Abralia veranyi*, was described from the Mediterranean in 1844 by Rüppell. It is characterized by the presence of five light organs on the eyeball of which the first and the last members are large and oval, the posterior one with a slight sinus, and there are four hooks on the tentacular club of which the proximal is minute, the second largest, and the others decreasing in size. There are four rows of minute suckers on the ends of the arms. The second species, *Abralia redfieldi*, was described by the author in 1955 and separated from the preceding species by the presence of five light organs on the eyeball all of which are round, three hooks on the tentacular club and two rows of suckers on the sessile arm tips.

A. veranyi is recorded from the Mediterranean, the eastern Atlantic from Madeira to West Africa, and the Western Atlantic from the Bahamas, Cuba and the Gulf of Mexico. *A. redfieldi* is known at present from the Florida Current off Miami and the coast of Cuba. The present species. It has been well figured and described by Pfeffer (1912). ing only two rows of minute suckers on the ends of the arms. It differs from both in having only two large hooks on the tentacular club and differs also from both in the arrangement and size of the light organs on the eyeball. It does not correspond to any of the known Indo-Pacific forms.

The specific name *grimpei* is given in honor of Dr. Georg Grimpe, the noted German teuthologist who contributed greatly to our knowledge of this genus.

KEY TO THE ATLANTIC SPECIES OF *Abralia*

1. 4 rows of suckers on the tips of the sessile arms; 4 hooks on the tentacular club; light organs on eyeball with large oval anterior and posterior members with a sinus in the dorsal margin of the posterior one; fins large, well over half the mantle length in the adult.

Abralia veranyi Rüppell, 1844

2 rows of suckers on the tips of the sessile arms; less than 4 hooks on the tentacular club; light organs on the eyeball all round; fins small.....2

2. 3 hooks on the tentacular club; light organs on eyeball round, 1st, 3rd and 5th large, 2nd and 4th small; body large and stout.

Abralia redfieldi Voss, 1955

2 hooks on the tentacular club; light organs on eyeball less clearly defined, 6-7 in number with anterior and posterior ones largest, 2nd and often next to last minute; mantle long and slender.

Abralia grimpei, n. sp.

Abralia juv.

Material. 1 juv., ML 6.8 mm, from Stn. RHB 551 from 57 meters, Feb. 6, 1954.

3 juv., ML 10.5, 9.5 and 11.6 mm, from Stn. RHB 560 from 46 meters, Feb. 22, 1954.

It does not seem possible to make a definite identification of the four specimens listed above. The tentacles are missing in all but the largest specimen from Stn. 560, in which it appears that the distalmost hook on the club is the largest. In this specimen the 1st and 5th light organs on the eyeball are nearly the same size as the 3rd and in this respect it most closely resembles *A. redfieldi*, but there seem to be four rows of suckers on the tips of the sessile arms which would place it in *A. veranyi*. The remaining two specimens from Stn. 560 have very large, rather round 1st and 5th photophores which would place it in the same species.

The smallest specimen in the series, from Stn. 551, seems to have smaller fins and a narrower body and the light organs of 1, 3 and 5 on the eyeball are of equal size. From these characters it would seem best to call it *A. redfieldi* but I hesitate to do so until the larval and juvenile stages and the accompanying morphological changes are known. In all of the specimens, the dorsal row of light organs on the ventral arms alone is present, and the photophores on the ventral surface of the head and mantle are much less numerous than in the adults.

? *Abraliopsis morissi* (Verany, 1837)

Onychoteuthis Morissii Verany, 1837, p. 100.

Enoplateuthis Morissii, Orbigny, 1848, p. 338.

Abralia Morissii, Gray, 1849, p. 50.

Abraliopsis Morissii, Pfeffer, 1900, p. 168.

Material. 1 ♂, damaged, ML 18.6 mm, from Stn. RHB 572 in 505 meters, Feb. 25, 1954.

1 ♀, damaged, ML 16.5 mm, from Stn. RHB 589, in 370 meters, March 22, 1954.

The present specimens are in such a poor state of preservation that definite identification is impossible. The distal ends of the ventral arms are missing in both specimens so that it cannot be determined if they possessed the three photophores at their tips. However, the much larger fins, the light organs arranged in more or less regular rows on the mantle, and the dark purplish violet buccal membrane all indicate that the specimens are referable to this species.

Pyroteuthis margaritifera (Rüppell, 1844)

Enoplateuthis margaritifera Rüppell, 1844.

Pterygioteuthis margaritifera, Pfeffer, 1900, p. 166.

Pyroteuthis margaritifera, Hoyle, 1902, p. 1.

Material. 2 ♀ ♀, ML 14.5 and 13.5 mm, from Stn. RHB 552, in 485 meters, Feb. 7, 1954.

These two specimens were the sole representatives of this common species. It has been well figured and described by Pfeffer (1912). They are easily differentiated from *Pterygioteuthis giardi* Fischer by the wide insertion of the fins, the presence of suckers on the ventral arms and the numerous large chromatophores on the dorsal surface of the head and mantle. This is a widely distributed species occurring in the Mediterranean Sea, Azores (Joubin), Madeira (Rees), Cuba (Voss). Joubin's specimen from the Azores was described as a new subspecies, *P. m. aurantiaca*.

Pterygioteuthis giardi H. Fischer, 1896

Pterygioteuthis giardi H. Fischer, 1896, p. 205.

Material. 4 ♂ ♂, ML 10.5 - 16.5 mm, 3 ♀ ♀, ML 8.4 - 19.0 mm, from Stn. RHB 553, in 57 meters, Feb. 7, 1954.

2 ♀ ♀, ML 18.0 and 14.0 mm, 2 ♀ ♀ damaged from Stn. RHB 555 in 560 meters, Feb. 10, 1954.

2 ♂ ♂, ML 12.8 and 8.3 mm, 3 ♀ ♀, ML 8.0 - 18.0 mm, and 1 damaged specimen, from Stn. 560, in 46 meters, Feb. 22, 1954.

1 ♂, ML 14.3 mm, 1 ♀, ML 15.6 mm and 3 badly damaged specimens from Stn. RHB 572, in 505 meters, Feb. 25, 1954.

1 ♂, ML 11.8 mm, 7 ♀ ♀, ML 5.3 - 18.0 mm, from Stn. RHB 574, in 46 meters, Feb. 25, 1954.

2 ♂ ♂, ML 11.0 and 13.4 mm, from Stn. RHB 575, in 505 meters, Feb. 26, 1954.

2 ♀ ♀, ML 16.0 and 20.0 mm, from Stn. RHB 587, in 46 meters, March 21, 1954.

The 34 specimens listed above were the most numerous of any species taken by the ATLANTIS on this cruise and the females were nearly twice as numerous as the males (10 males, 18 females). Their vertical distribution extended from 46 meters to 560 meters but no particular change in level seemed to occur with increase in size.

Pfeffer (1912) has discussed the relationship of this genus with *Pyroteuthis* and considered it to be a subgenus of the latter. However, the hectocotylization of the left arm in *Pterygioteuthis* in contrast with the right arm in *Pyroteuthis* seems alone to be of sufficient weight to keep it at the generic level.

Whether, as Pfeffer suggests, there are two races or subspecies of this species, one in the Atlantic and the other in the Pacific (*P. giardi hoylei*) must await the analysis of a larger number of specimens than is now available. Apparently a closely related species, *P. gemmata* Chun, occurs in the South Atlantic, but the author has seen specimens from the tropical Atlantic referred to *P. giardi* which had the peculiar faceted light organs of the former species.

Family OCTOPODOTEUTHIDAE Berry

Octopodoteuthopsis megaptera (Verrill, 1885)

Ancistrocheirus megaptera Verrill, 1885, p. 399.

Octopodoteuthopsis megaptera, Pfeffer, 1912, p. 223; Voss, 1955, p. 125.

Material. 1 juv., ML 11.7 mm, from Stn. RHB 550, in 329 meters, Feb. 6, 1954.

This small specimen has had the posterior end of the mantle cut off even with the fins, and if intact would probably have measured about 14.0 mm. The fins are very broad and somewhat narrow, 19.0 mm by 11.0 mm. The funnel organ has the peculiar hollowed out ventral pads described by Voss (1955, p. 125). The arms are apparently in the order 3.4.2.1, the third pair much longer than the others. None of the light organs described for this species were observable.

The ventral surface of the head and mantle is liberally spotted with small reddish brown chromatophores, and there is a transverse row of larger, dark brown chromatophores across the ventral surface of the head at the midpoint of the eyes.

Family ONYCHOTEUTHIDAE Gray

Onychoteuthis banksi (Leach, 1817)

Loligo banksi Leach, 1817, p. 141.

Onychoteuthis banksi, Orbigny, 1826, p. 61; Voss, 1955, p. 129.

Material. 1 juv., ML 16.5 mm, from Stn. RHB 551, in 57 meters, Feb. 26, 1954.

1 juv., ML 10.5 mm, from Stn. RHB 553, in 57 meters, Feb. 7, 1954.

5 juv., ML 6.6-9.5 mm, from Stn. RHB 574, in 46 meters, Feb. 25, 1954.

3 juv., ML 5.3-17.0 mm, from Stn. 581, in 95 meters, Feb. 26, 1954.

The 10 juveniles listed above were easily distinguished as belonging to this species. The rows of chromatophores in the midline on the dorsal surface, small fins, and sharply curved and projecting end conus of the gladius serve to distinguish this from all other known teuthoid larvae and juveniles. As might be expected of a surface pelagic species, the larvae all came from the shallower stations.

Family HISTIOTEUTHIDAE Verrill

Calliteuthis reversa Verrill, 1880

Calliteuthis reversa Verrill, 1880, p. 393.

Material. 1 ♂, ML 33.5 mm, Stn. RHB 450, in 137 meters, July 16, 1953. UMML 31.190.

1 ♀, ML 42.0 mm, Stn. RHB 584, in ??? meters, March 4, 1954. UMML 31.192.

1 ♀, ML 34.5 mm, Stn. RHB 591, in 524 meters, March 22, 1954. UMML 31.191.

2 ♀ ♀, ML 22.5 - 25.0 mm, Stn. RHB 555, in 560 meters, Feb. 10, 1954. UMML 31.193.

Five specimens, tentatively identified as *C. reversa*, were taken by the BLUE DOLPHIN and the ATLANTIS. Four of these, all females, seem similar to those described by me (Voss, 1956) from the Gulf of Mexico. Their measurements and indices are given in Table 3.

The mantle is short, cone-shaped, widest at the anterior margin and bluntly pointed. The fins are small, round, indented posteriorly, and projecting slightly beyond the end of the mantle. In all the arm suckers are smooth on the proximal half and bear about twelve small, semi-circular teeth on the distal half, the teeth minute and difficult to see basally, distinct distally. The tentacular suckers are minutely but distinctly armed with sharp teeth numbering about 60 on the largest sucker of the largest specimen. This may be compared with about 33 teeth from the Gulf of Mexico specimens. The photophores are few and scattered with three rows on the ventral arms. The dorsal member of the funnel organ bears a large flap on each lateral arm.

The fifth specimen, a male, differs considerably from the others. The mantle is more elongate and slender, with nearly parallel sides on the anterior half. The arm suckers are nearly smooth proximally armed with very minute teeth which are hardly discernible, but are more evident distally. The tentacular suckers are also toothed, but very minutely. In addition, the tentacles are quite short. There are no flaps on the dorsal member of the funnel organs, these being replaced by low mounds.

TABLE 3
MEASUREMENTS AND INDICES OF 5 SPECIMENS OF
Calliteuthis reversa Verrill, 1880.

Stn. No.	584	591	555	555	450
Sex	♀	♀	♀	♀	♂
ML	42.0	34.5	22.5	25.0	33.5
MWI	56.0	58.0	55.5	54.0	37.4
HWI	64.2	66.8	66.7	56.0	43.3
HLI	69.0	66.8	66.7	68.0	40.3
FLI	37.0	36.3	37.3	38.0	32.9
FWI	71.5	65.2	62.3	66.0	53.8
Arms I	85.0	63.0	33.0	41.0	33.5
II	101.0	61.0	37.0	44.0	38.0
III	101.0	70.0	38.0	44.0	37.5
IV	87.5	57.0	33.0	39.0	32.0
TLI	303.0	336.0	235.0	280.0	110.0
CLI	47.7	49.3	35.6	40.0	26.9
MAI	241.0	200.0	169.0	176.0	113.0

This last specimen compares very favorably with the original description and measurements of the holotype given by Verrill (1880). However, at this time we know too little about sexual differences in this group to even surmise whether all five specimens belong to *C. reversa* or whether they represent two distinct species. A revision of this genus is now underway by the author and it is hoped that some of the perplexing problems in this group may be cleared up.

Family OMMASTREPHIDAE Gill

Ommastrephid larvae (*Rhynchoteuthis*)

Material. 1 juv., ML 3.3 mm, Stn. RHB 560 in 46 meters, Feb. 22, 1954.

2 juv., ML 5.1 mm, one damaged, Stn. RHB 574 in 46 meters, Feb. 25, 1954.

These three small larvae cannot be identified to species at this time. The entire problem of the *Rhynchoteuthis* larvae has yet to be solved, although it has been assumed that at least some of the known larvae belong to *Ommastrephes pteropus* and *O. bartrami*. Various stages in

the development of these larvae have been illustrated by Pfeffer (1912), who considered that there might be two species represented in his material. Additional comments on this problem have been given by Robson (1948). This form is commonly found in the plankton and it is somewhat surprising that the ATLANTIS took so few during this cruise.

Family CHIROTEUTHIDAE Gray

Mastigoteuthis sp.

Material. 1 specimen, ML 36.0 mm, Stn. RHB 572 in 505 meters, Feb. 25, 1954.

A single specimen, very badly damaged, with all of the arms mutilated and tentacles missing, was obtained at the above station. Because of its condition the specimen is unidentifiable. The skin is lacking over almost the entire surface, the greater part of all of the arms is missing and the head is detached from the body. However, just anterior to and somewhat ventral to the eyes is a large photophore on either side. These may be double or both may have been torn in two. According to Degner (1925), only two species of this genus have photophores on or near the eyes, *M. glaucopsis* and *M. hjorti*. The shape of the fins and the posterior extremity of the body do not agree with the figures of *glaucopsis* nor does the animal fit the description of *hjorti* in all respects.

Liocranchia reinhardti (Steenstrup, 1856)

Leachia Reinhardti Steenstrup, 1856, p. 200.

Cranchia Reinhardti, Steenstrup, 1861, p. 76.

Loligopsis Reinhardti, Tryon, 1879, p. 165.

Perothis Reinhardti, Rochebrune, 1884, p. 25.

Liocranchia Reinhardti, Pfeffer, 1900, p. 194.

Material. 1 specimen, ML 38.5 mm, Stn. RHB 560 in 46 meters, Feb. 22, 1954.

The present specimen shows some small differences from the typical specimens of this species, but they do not warrant any change in the identification. The fins are large and slightly broader than long, with no indentation on the posterior median border. The V shaped rows of tubercles on either side of the mantle at the fusion with the funnel are large with conspicuous tubercles, roughly alternating between large tri- or quadrifid tubercles and simple ones. At the apex of the V is a large multicuspid tubercle much larger than any described or figured in the literature. Dorsally there is a row of widely spaced simple tubercles in the midline on the gladius or lanceola, but in the posterior widened section the tubercles are few and small.

In my paper on the Cuban cephalopods (Voss, 1955), I erroneously gave the specimen recorded in that paper as the first record from the Western Atlantic, but a perusal of Pfeffer's 1912 monograph yielded a record by Issel from the Caribbean.

Pyrgopsis lemur Berry, 1920

Pyrgopsis lemur Berry, 1920, p. 298.

Material. 1 specimen, ML 21.0 mm, Stn. RHB 560, in 46 meters, Feb. 22, 1954.

This specimen seems to be conspecific with Berry's species according to the published preliminary description. The mantle is long and slender, completely colorless and tapers to a long narrow point posteriorly. The ventral surface of the mantle bears two longitudinal rows of cartilaginous tubercles consisting of large, spinous tubercles with small simple ones between them. The tubercle rows appear to be less than $\frac{1}{4}$ the mantle length. The fins are slightly broader than long, transversely elliptical with smooth outlines. The gladius is visible through the mantle but was not distinct enough for descriptive purposes.

Degner (1925) has compared his material of *P. atlantica* with the present species, and has remarked upon its similarity to *P. pacifica* and *P. schnehenageni*.

The present specimen is apparently only the second record of this small cranchiid.

Order OCTOPODA

Family OCTOPODIDAE Orbigny

Scaevargus unircirrhus (Orbigny, 1840)

Octopus unircirrhus Orbigny, 1840, p. 70.

Scaevargus unircirrhus, Tiberi, 1880, p. 12.

Material. 3 juv., ML 5.1, 6.0 and 7.5 mm, Stn. RHB 560, in 46 meters, Feb. 22, 1954.

4 juv., badly damaged, Stn. RHB 572, in 505 meters, Feb. 25, 1954.

2 juv., ML 7.5 and 7.5 mm, Stn. RHB 574, in 46 meters, Feb. 25, 1954.

Macrotritopus stage

The present specimens are all larval or juvenile forms with the typical extreme elongation of the third arms which has given this stage the generic name *Macrotritopus*. The identity of this species has long been in doubt and until recently about six separate species have been described. In 1954 Rees showed that all of the known specimens of

this genus are young specimens of *Scaeurus unicolor*. The present specimens present no unusual features and agree well with all of the particulars enumerated by Rees. The various species assigned to the genus *Macrotritopus* are not listed here but a full larval synonymy is given in the paper cited above.

Eledonella pygmaea Verrill, 1884

Eledonella pygmaea Verrill, 1884, p. 145.

Material. 1 ♂, ML ?, from Stn. RHB 572, in 505 meters, Feb. 25, 1954.

This small specimen is in very poor shape and is listed here only to complete the record of the specimens in the collection.

TABLE 4

DATA FOR ALL STATIONS AT WHICH CEPHALOPODS WERE TAKEN.

Station	Date	Location	Gear	Time	Depth in meters
450	VII/16/54	39°45'N, 71°08'W	IKMT	2018-2125	137
550	II/6/54	25°53'N, 79°46'W	IKMT	1513-1718	330
551	II/6/54	26°25'N, 79°45'W	IKMT	1957-2159	57
552	II/7/54	26°34'N, 79°04'W	IKMT	1545-1722	485
553	II/7/54	26°35'N, 79°28'W	IKMT	2339-0144	57
555	II/10/54	25°26'N, 76°03'W	IKMT	0110-0419	560
560	II/22/54	18°43'N, 65°10'W	IKMT	2000-0040	46
572	II/25/54	20°17'N, 65°02'W	IKMT	0242-0606	505
574	II/25/54	20°12'N, 65°19'W	IKMT	2000-2400	46
575	II/26/54	19°22'N, 65°57'W	IKMT	1047-1453	505
581	III/2/54	19°21'N, 66°20'W	IKMT	0328-0603	95
582	III/2/54	18°37'N, 66°05'W	IKMT	1939-2311	505
584	III/4/54	18°55'N, 66°10'W	IKMT	2000-0015	Surface to 415
587	III/21/54	26°22'N, 76°10'W	IKMT	2003-2111	46
589	III/22/54	26°08'N, 76°23'W	IKMT	0310-0542	370
591	III/22/54	25°32'N, 77°15'W	IKMT	2135-0103	524

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